... OF THE NAVY
... ENGINEERING
... No. 184

INSTRUCTIONS

FOR THE

CARE AND OPERATION OF

REFRIGERATING PLANTS

NAVY DEPARTMENT
BUREAU OF ENGINEERING

(Revised Edition, 1921)

WASHINGTON
GOVERNMENT PRINTING OFFICE
1921

DEPARTMENT OF THE NAVY
BUREAU OF ENGINEERING
N. ENG. 144

INSTRUCTIONS

FOR THE

CARE AND OPERATION OF

REFRIGERATING PLANTS

NAVY DEPARTMENT
BUREAU OF ENGINEERING

(Revised Edition, 1921)

WASHINGTON
GOVERNMENT PRINTING OFFICE
1921

CONTENTS.

Section I.—DENSE-AIR MACHINES.

OPERATION.

ADJUSTMENTS.

SUGGESTIONS.

TROUBLES.

Section III.—ETHYL-CHLORIDE MACHINES.

Section IV.—AMMONIA MACHINES.

OPERATION.

INSTRUCTIONS FOR THE CARE AND OPERATION OF REFRIGERATING PLANTS.

NAVY DEPARTMENT,
BUREAU OF ENGINEERING,
May 2, 1921.

These instructions have been compiled for the information and guidance of the naval service. They are applicable to the types of refrigerating plants installed on board naval vessels.

It is requested that, as additional information becomes available, commanding officers submit criticisms of these instructions and recommendations as to improvement of the methods and procedure outlined herein.

R. S. GRIFFIN,
Engineer-in-Chief, United States Navy.

NAVY DEPARTMENT,
Washington, D. C., May 12, 1921.

The "Instructions for Care and Operation of Refrigerating Plants" are approved for issue to the naval service for information and guidance. The instructions and recommendations contained therein will be followed on all vessels.

EDWIN DENBY,
Secretary of the Navy.

Section 1.—DENSE-AIR MACHINES.

OPERATION.

1. Principle.—The operation of the machine consists in drawing in air from the system and compressing it to three times its absolute pressure. The work done on the air in compressing it heats it, and it is then passed through the cooling coils, where the circulating water and the cool return air extract the heat of compression before it enters the valve chest of the expander cylinder. In the expander cylinder the air expands doing work, thereby losing heat, so that it is discharged at a very low temperature, usually about 100 degrees below the temperature at which it entered the expander cylinder, when this is about 60 degrees. The number of degrees of reduction of temperature is somewhat greater when the incoming air is warmer and somewhat less when its temperature is much below 60 degrees.

2. Starting.—If the machine is new and is to be started for the first time, it will be necessary to see that the system is clear of sand and scale, as any hard substance in the system will cause endless trouble by cutting the valves, valve seats, cylinders, and piston packing. The parts of the machine carrying air and the whole system of piping should be blown out with air from the ship's air line.

Before starting the machine, when new or after being shut down for a period, see that the valves on the suction and discharge lines to the circulating pump are open, the by-pass valve open, the main valves on the cold air and return air closed, the cylinder drains open, the valves on the hot-air blow line to the expander cylinder closed, and the drain valves on the expander cylinder and the pet cocks on the traps open. Have all bearings properly lubricated, jack the machine over by hand, and start engine slowly after opening exhaust valve. See that circulating water is being supplied. Close steam cylinder drains. When the discharge from the drain valves on the expander and the pet cocks on the traps is free of oil and moisture, close them and gradually build up the pressure to 125 pounds on the compressor. Open the sight-feed lubricators of the compressor and expander cylinders.

When a pressure of 125 pounds is reached, blow down to 100 pounds through the drain on oil trap and expander drain cocks, and while the machine is building up the pressure, open the pet cocks on the traps and the expander drain valves at frequent intervals, and at each opening keep them open until the discharge is free of oil and moisture. When the pressure has been built up to about 65 pounds on the expander and 235 pounds on the compressor cylinder, cut the machine in on the system by opening the valves on the cold air and return air lines and closing the by-pass valve.

3. Speed.—The speed of the machines for everyday service may be anywhere from 60 to 100 revolutions per minute for the 2 and 3 ton machines and from 75 to 120 revolutions for the smaller ones. For short periods the larger machines may be run up to 120 revolutions per minute and the smaller ones to 140 revolutions; but the normal speed, if the machine and system are in good condition, should be 60 for the larger machines and 75 for the smaller ones, and if the meat in the cold-storage rooms is well frozen and the temperature can be kept below freezing point with a slower speed, the machines should be run at as low a speed as practicable.

4. Pressures.—Within certain limits the pressure carried has little effect upon the efficiency of the machine so long as the high pressure is approximately three times the low pressure, when these are expressed in absolute pressures. It is the correct ratio of pressures and the circulation of the air in the system which counts for efficiency rather than high pressures, so that with a correct pressure ratio low pressures and high speed will give better economy than high pressures and low speed. For customary service pressures of 65 to 70 pounds per gauge on low pressure and 230 to 245 pounds per gauge on high pressure with a moderate speed should be used, but for maximum capacity the pressures should be high and the speed high.

5. Cylinder lubrication.—It is of the utmost importance that the oil used for internal lubrication and for the rods should be the oil that is especially provided for that purpose. It is a good plan to mark the oil

cans or distinguish them in some way so that there will be little chance of the oil for bearings being used by mistake for internal lubrication.

For internal lubrication about five or six drops of oil per minute for the compressor cylinder and none for the expander is sufficient, but the manufacturers recommend about three drops of oil per minute for the expander cylinder. It is desirable that the amount of oil used for internal lubrication be reduced to a minimum consistent with satisfactory lubrication, because the oil used is carried over into the system and forms a coating on the inside of the pipes which reduces their conductivity. On some ships using no oil for the expander cylinder it has been found advantageous to use a few drops of oil in the primer pump two or three times a day.

6. **Lubrication of piston rods and valve stems.**—By means of the oil cups on the piston-rod and valve-stem stuffing boxes about two drops of oil per minute should be dropped into the stuffing boxes, but if the packing of the rods and stems is in good condition and the speed of the machine not over 60 revolutions per minute, no lubrication of the piston rods and valve stems is necessary, as the oil in the air affords sufficient lubrication. On some ships it is the practice to use the lubricator only on the steam piston rod.

7. **Lubrication of bearings.**—For lubricating the bearings about 4 or 5 drops of oil per minute is generally used, but the amount used depends upon the condition of the bearings and the speed of the machine.

8. **Blowing down.**—Once a day it is necessary to clean the machine by heating it up and blowing out all the oil and ice deposits. This is done as follows: While the machine is running slowly and the compressor pressure has dropped to 150 pounds, the by-pass valve on the line from the oil trap to the return-air line is opened, the main valves on the cold-air line and the return-air line are closed, the valve on the hot-air blow line from the compressor to the expander is opened, and then steam is turned on the jacket of the oil trap very slowly and the drain from the jacket opened. Run this way for about 30 minutes, frequently opening the pet cock on the oil trap and the drain valves on the expander so as to remove all the oil and moisture. Then shut off the hot-air blow and the jacket steam and run the machine on the by-pass until it is certain that the air from the expander cylinder is cold enough, then cut the machine in on the system, closing the by-pass.

In spite of the proper draining of the moisture trap a certain amount of moisture will get into the expander; therefore it is desirable to open the drain valves on the expander and the traps about once an hour and blow out the oil and moisture. On some ships it is the practice to leave the cock on the primer-pump trap slightly open at all times in order to drain the moisture out of the newly supplied air. If the amount of oil used for internal lubrication has been reduced to a minimum and the drains on the expander and the oil trap opened for a few minutes each hour, it is practicable to reduce the blowing down to once every other day.

9. **Piston-rod and valve-stem packing.**—The packing of the piston rods and valve stems consists of a few rings of metallic packing, then a hollow oiling ring, then a few turns of L. P. spiral packing. The setting of a definite regular time for repacking piston rods and valve stems will prevent troubles and shutdowns; therefore, it is recommended that the metallic packing be examined every two months to see that ends are not butting. At this time the soft packing should be renewed, using L. P. packing, as

asbestos packing will score the rods if used in stuffing boxes of the air cylinders. In replacing this packing it is absolutely necessary to place the oiling ring in the correct position opposite the hole for the oil pipe; otherwise trouble will be experienced with hot rods and burned packing. The stuffing-box glands should be set up a little more than hand tight and great care should be taken to see that excessive friction is not caused by setting up too hard on these glands. The expander piston rod should run cool at all times, and if this rod warms up the packing should be overhauled and renewed, if necessary. Leaks around the stuffing boxes may be discovered by swabbing the rods with oil, and if a very little setting up on the glands does not stop the leakage, it is far better to overhaul and renew the packing than to overload the machine with useless friction and run a chance of heating the rods. On one ship, with an electric-driven 3-ton machine, the stuffing boxes were set up so hard that it required 15 horsepower to run the machine at 60 revolutions per minute with no pressure on the system.

10. **Packing of expander and compressor pistons.**—The pistons of the expander and compressor cylinder are packed with leathers or cast-iron rings. When packed with leathers those in the compressor usually last much longer than those in the expander cylinder. The expander leathers are often cut by ice chips formed in the cylinder due to the low temperature in this cylinder, but they should last about eight to ten weeks. In overhauling, it is a good plan to turn the expander leathers around so that the same part of the leather is not exposed to the most severe conditions at the cylinder ports. Much time will be saved if a former is used to form new leathers before they are installed, but if this is not used it is a good plan to insert the first new leather in the rear end of the piston, and in a day or two, when this leather is formed, transfer it to the crank end of the piston and put a new leather in the rear end.

All of the late dense-air ice machines have cast-iron rings on both the compressor and expander cylinder.

11. **Oiling walls of expander cylinder.**—The top side of the bore of the expander cylinder will rust very quickly after the machine is shut down; therefore, before shutting down for a long period a little extra oil should be fed into this cylinder. It is good practice to remove the cylinder head, wipe out and oil the cylinder walls if the machine is to be idle for a week or more.

12. **Circulating water.**—The constant supply of an adequate amount of cooling water is of vital importance, because the stoppage of the circulating water for only a few minutes while the machine is in operation may result in the scoring of the compressor and expander valves and the burning of the piston leathers.

It is a good plan to have the machine so connected that circulating water may be taken from the flushing system.

13. **Draining coils of system.**—When the machines have been shut down for some time the cooling coils in the cold rooms will be thawed out and should be drained of any contained moisture and oil. These coils should not be thawed out or blown out with steam, as it is liable to start leaks, but should be blown out with air from the ship's air lines.

14. **Cleaning out the ice-making box.**—The oil in the cold air will gradually cover the inside surface of the ice-making box and reduce the conductivity of the walls, so that it is good practice to blow out the box with hot air or low-pressure steam when the machine is shut down for

some time. Some ships make a practice of boiling out the ice making box when the plant is given a thorough overhaul.

ADJUSTMENTS.

15. Alignment.—The cylinders should line up at right angles to the crank shaft with their center lines parallel to the guides, and in practically every machine the cylinders will have been so installed, and it should be unnecessary to check up this alignment unless excessive trouble is experienced with piston-rod packing and hot bearings.

The crosshead slipper is subject to wear, and unless it is of sufficient thickness to hold the piston rod in the center of its stuffing box excessive trouble will be experienced with the piston-rod packing. To determine whether or not the piston rod moves in the axis of the cylinder, remove the gland, withdraw the packing, and caliper the distance between the rod and the stuffing box with the piston at each end of its stroke; if the piston rod is found high or low in the stuffing box, correct this by removing or adding liners back of the crosshead slipper so as to lower or raise the crosshead end of the piston rod.

16. Adjustment of bearings.—The method of scraping and fitting the bearings is the same as for other bearings of this size and type, and the clearances must be governed by the condition of the journals and the alignment and size of the machine. With journals in good condition the main bearings should be adjusted by taking leads so as to give a clearance of about 0.005 inch.

The crosshead bearings should be adjusted so that the connecting rod will swing freely, by first setting up on the gib until the brasses touch the pin and then slacking back a small amount and trying the swing of the connecting rod.

The crank bearings are adjusted by taking leads so as to give a clearance of about 0.005 inch.

17. Fitting crosshead slipper and guides.—The crosshead slipper and guides are scraped to a surface plate and adjusted so that the crosshead will slide freely, usually with a clearance of about 0.004 inch.

18. Fitting bushings of valve gear.—The bushings on the rocker arms of the valve gears should not be set up without disconnecting one end of rod and swinging it to see that they are not too tight. These adjustments are made with a set screw, and, if not carefully made, may be the cause of much trouble.

19. Fitting eccentric straps.—The eccentric straps should be adjusted by swinging, in preference to taking leads, as the straps are easily sprung.

20. Clearance of pistons.—The clearance of the pistons of the compressor and expander is only one-eighth of an inch. On account of this small piston clearance, care should be exercised, when adjusting bearings, to see that the clearance is the same at both ends; also, when overhauling or renewing piston leathers, to see that the piston rod does not unscrew from the crosshead. A tram should be made and marks properly made on the crosshead and the piston rod near the crosshead for checking up the position of the piston rod.

21. Clearance of primer-pump plunger.—The clearance of the plunger of the primer pump at the end of its compression stroke should be a scant sixteenth of an inch, and may be as small as one thirty-second. If set too close the plunger is liable to expand when hot and may strike. The

clearance of this plunger has an important effect upon the efficient operation of the machine and should be very small if there are many air leaks in the machine or system, but if there are few leaks the clearance should be increased so that the relief valve will not continually lift at the end of the compression stroke.

22. Setting the slide valves.—The setting of the slide valves is similar to that of setting a slide valve on any steam engine, except with additional details due to the design of the valve chest and the valves.

23. Putting the crank on the center.—In setting the slide valves of any cylinder it is necessary to put the corresponding crank on the dead center, so that if a tram and center marks are not already available it is necessary to make a tram and punch the center marks. To make a tram, secure a steel rod about three-eighths inch in diameter and of sufficient length when formed to reach from some convenient point on the bedplate to the face of the flywheel. Grind both ends to a point and bend one end, or both, if necessary, so that points will drop into center-punch marks to be made on face of flywheel and on bedplate.

When tram is ready place a deep center-punch mark on the bedplate for the permanent use of the tram. Jack the machine until the crosshead whose crank is to be placed on center is about 2 inches from end of its stroke, scribe a mark across the crosshead and crosshead guide and at the same time, with one end of the tram in center-punch mark on the bedplate, scribe a light mark on the face of the flywheel with the other end of the tram; then jack the crank over the center until the marks on the crosshead and crosshead guide come in line, then with tram scribe a light mark on face of flywheel as before. This gives two tram marks on the face of the flywheel, each made when the crank was the same distance from the dead center; bisect the distance between these two marks and place deep a center punch mark at this central point; jack the machine until the tram point drops into this center-punch mark when the other tram point is held in the mark on the bedplate; the crank will then be on the dead center. This operation should be repeated until marks are placed for both dead centers for all three cranks.

24. Setting lower valve or expander cylinder.—With both upper and lower slide valves removed from the valve chest, mark the valve-chest walls with chalk, and, using a small straightedge, and a square with a scriber transfer the ports in the valve seat to the walls of the valve chest. With a square and a scriber transfer the valve admission ports from the bottom to the top of the valve. Replace the lower valve and place a straightedge on the top of the valve and with a scriber draw a line on the valve-chest wall parallel with valve seat and intersecting the previously drawn vertical lines which represent the ports in the valve seat, and mark the intersections with a center punch. Put the expander crank on the dead center and by means of the adjusting nuts set the valve by observing the port lines on top of the valve and the valve-seat port marks on the valve-chest walls so that it will have a lead of $\frac{1}{32}$ or $\frac{1}{16}$ of an inch, depending upon the size of the machine as shown in the table. Place the expander crank on the other dead center and see that the lead is the same, then set up on the adjusting nuts and lock nuts so as to leave a clearance of about 0.002 inch between the faces of adjusting nuts and the valve. This clearance is sufficient to allow the valve to seat properly and not enough to cause a knock.

25. Setting upper valve of expander cylinder.—Replace the upper valve and mark the stroke of the expander piston on the expander crosshead guide then jack the machine until the upper valve begins to cut off, and measure on the guide the distance the crosshead has traveled from the end of its stroke, which should be from $3\frac{1}{4}$ to $6\frac{1}{4}$ inches, depending on the size of the machine as given in the table; repeat this operation for the other end of the valve, and, if the measured distances of crosshead travel are not equal, shift the valve by means of the adjusting nuts until these distances are equalized, then set up on the lock nuts, and the valve setting for this cylinder is completed.

Size.	Type.	Steam cylinder.		Expander cylinder.		Compressor cylinder.	
		Lower valve lead.	Upper valve closes.	Lower valve lead.	Upper valve closes.	Lower valve closes.	Upper valve opens.
					Inches.		*Inches.*
$\frac{1}{2}$	Vert.	Notch.	....	$\frac{1}{32}$	$3\frac{1}{4}$	$\frac{1}{32}$ lap.	$4\frac{1}{4}$
1	Vert.	Notch.	....	$\frac{1}{32}$	$3\frac{1}{2}$	$\frac{1}{8}$ lap.	$4\frac{3}{4}$
1	Hor.	$\frac{1}{16}$	....	$\frac{1}{16}$	4	$\frac{1}{8}$ lap.	$5\frac{1}{4}$
2	Hor.	Notch.	....	$\frac{1}{16}$	$5\frac{1}{4}$	$\frac{1}{8}$ lap.	$6\frac{3}{4}$
3	Hor.	$\frac{1}{16}$ +Notch.	From 4 to 8 ins.	$\frac{1}{32}$	$6\frac{1}{4}$	Line and line.	$6\frac{3}{4}$

26. Setting lower valve of compressor cylinder.—The procedure in setting the lower valve is the same as in setting the lower valve of the expander cylinder, except that this valve has inside admission and the valve is given a lap instead of a lead, the amount, which should be the same at each end, being given in the table for each size of machine. Since the construction of this valve does not give a surface on top to which the admission port may be transferred, a thin piece of wood or heavy cardboard must be secured on top of the valve, to the top of which the admission port of the valve is transferred for use in setting the valve.

27. Setting upper valve of compressor cylinder.—The procedure in setting the upper valve is the same as in setting the upper valve of the expander cylinder, except that this valve should just begin to open when the jacking is stopped for the measurement of the distance the crosshead has traveled, and this distance should be from $4\frac{1}{4}$ to $6\frac{3}{4}$ inches, depending on the size of the machine as given in the table.

28. Setting of valves of steam cylinder.—The setting of the steam valves is the same as on any steam engine, the position of the valve being given in the table. If the steam cylinder is fitted with a riding cut-off valve, the procedure in setting this valve is the same as for the upper valve of the expander cylinder, the data for setting this valve being found in the table.

29. Marking position of valves.—After the valves are once properly set, their position should be marked with reference to a fixed point on the valve-chest wall. This will save time when the valves are removed for examination or refitting, as they may be replaced by these marks instead of resetting them. The valves and the valve seat should be well lubricated before the valves are replaced.

30. Taking indicator cards.—Indicator cards taken from the expander and the compressor cylinder will show whether or not the valves are properly set and functioning properly, and are of very great value in locating the cause of inefficient operation if it is due to leaking or improperly set valves.

31. Adjustment of primer-pump valves.—The valves of the primer pump are very important parts of the machine and should be carefully adjusted. The suction valve is fitted with a comparatively weak spring, the tension of which is adjusted by a nut and lock nut on the valve stem. The tension on this spring should be just enough to insure that the valve is held to its seat, as any greater tension may prevent the valve lifting on the suction stroke and any less would cause the valve to remain unseated with the consequent loss of air on the first part of the compression stroke. The usual lift of this valve is from $\frac{1}{16}$ to $\frac{3}{32}$ inch. On the larger machines the operator can tell whether or not the suction valve is functioning properly by the fact that, as a rule, when working properly it makes a light chattering noise. On the 2-ton and smaller machines the operator, by placing his fingers on the suction holes in the primer-pump plunger, can tell whether or not the pump is taking air.

The lift of the primer-pump discharge valve is limited by a stop piece over the valve, the usual lift being from $\frac{1}{32}$ inch to $\frac{3}{64}$ inch. This valve should be carefully fitted because, if it leaks, the primer pump is ineffective and the high-pressure air leaking into the pump barrel will keep the suction valve seated, thereby giving the impression that the adjustment of the suction-valve spring is faulty. The valve spring is usually made of steel and frequently corrodes and breaks. Bronze springs give good service and are not so liable to break. This valve should be carefully ground in; the usual method of testing one is to see that no shoulder exists, then mark seat and disk by drawing a lead pencil across seat, enter disk and turn same carefully against the seat and examine the seat to see if the pencil marks are cut. If the disk is allowed to wabble while turning, it will give a false impression, if the valve seat is worn slightly oval. If this valve is not properly fitted, it is liable to stick when it expands under the influence of the heat generated by the compression of the air.

SUGGESTIONS.

32. Connection to ship's air line.—If a connection is installed between the ship's air-pressure line and the discharge from the primer pump, the system may be quickly filled with air, so that much time may be saved on starting up or the machine may be run with the primer pump not operating properly. If such a connection is made, a drain should be fitted to the connection near the ice machine and care taken to thoroughly drain all the moisture from the connection before admitting any air to the refrigerating system.

33. Drain or steam line to trap.—A drain valve should always be fitted in the steam line to the jacket of the cold-air trap in order that any water may be drained out of this line before use and to make certain that the cut-out valve is not leaking steam into the jacket of the trap while the machine is running.

34. Drain on cold-air piping.—If drains are fitted to each line of piping beyond the machine, it is possible to tell whether any valve in the piping system is leaking without disconnecting any of the piping.

35. Drain on ice-making box.—Drains should be fitted on the bottom of the ice-making box, as some moisture is almost certain to collect in the box.

36. Drain on manifolds.—On some ships drains have been fitted to valve manifolds in the refrigeration system in order to drain the moisture that frequently collects there.

37. Drains on recooler.—On some ships a drain has been fitted to the recooler near the bottom of the low-pressure head for use in draining out any oil that might collect in the recooler.

38. Relief valve on ice-making box.—Good practice requires the installation of a relief valve on the ice-making box, as this is the weakest part of the system and several of these boxes have been cracked by excessive pressure.

39. Wire-gauze screen over primer-pump suction.—A wire-gauze screen should be placed over the suction of the primer pump in order to prevent the possible drawing into the system of dirt, waste, or other foreign matter.

40. Ice-making box used as a trap.—When not making ice it is a good idea to close only the discharge valve from the ice-making box, leaving the inlet valve open. Under these conditions the ice-making box is used as an oil and moisture trap, and it should be drained from time to time.

41. Reverse connections to ice-making box.—In tropical waters, on ships with small ice-machine capacity, where the machine is required most of the time directly on the cold storage, it has been found advantageous to fit cross connections to the ice-making box so that return air from the cold-storage system can be used on this box. With this connection it is possible to chill the water in the ice cans before putting the cold air directly on the ice-making box, and so reduce the time of operation under the latter conditions.

42. Recooler made on board ship.—When no recooler is installed and trouble is experienced with the cold storage, a very efficient recooler can be constructed on board ship and installed in about four hours. With circulating water over 80° F., the *New Orleans* was unable to keep down the temperature of her cold storage, so a recooler was made for a 1-ton machine by using a 4-inch pipe about 7 feet long. Heads were made of brass to form a tube sheet and screwed on each end of the pipe. Holes were drilled into these heads to take condenser tubes. The condenser tubes were expanded on each end and ferrules driven into ends of tubes to stiffen them and keep them from working loose. The cooler was fashioned after a feed-water heater, the high-pressure air going through tubes, the flow being so that return air entered at top of shell, at same end where high-pressure air left recooler on its way to the expander. The return air left opposite end of recooler from top of shell and air from cooler entered tubes at this end. This caused the coldest air to come in contact with coldest surfaces. The cooling medium was brought to close the air to be cooled by using small tubes. This recooler is very efficient.

The cooler when complete was clamped to the deck beams over the ice machine and lagged. The pipes were measured up, cut, and threaded. The necessary valves and fittings were drawn out. Then the machine was shut down and the old pipes removed. The lines were cut and valves inserted so that machine could be run as before in case the cooler failed. The connections were all made and the machine running within a few hours' time. The result was that there was no trouble with the tempera-

ture of the cold storage. Afterwards a cross connection was fitted so that machine could be run on cold storage and return through ice box. When this was done, there was no more trouble about making ice along the coast of Mexico.

43. Heater for air blow-out.—In blowing out the pipes of the cold-storage system heat will materially aid in clearing the system of oil, but the use of steam for blowing out the system is objectionable on account of the danger of starting leaks. Some ships use the machine itself with the hot-air blow line open to blow out the system, but this is dangerous on account of the tendency to overheat the machine. The best plan is to make a small heater like a bathroom heater and use air from the ship's compressed-air line for blowing out the system and steam on the heater for heating the air, as, in this way, the temperature of the air used for blowing out can be regulated.

44. Record of spares.—A record of all spare parts, with their location, should be kept up to date and available in case of breakdown, as the saving of thousands of pounds of fresh provisions, besides the comfort and the health of the crew, may depend upon the quick repair of the machine.

TROUBLES.

45. Pressures correct and ratio correct, but machine not effective.—If the machine maintains the correct pressure and the correct ratio of pressures, but fails to maintain the usual low temperatures, the trouble is probably due to one of the following causes:

Insufficient circulating water.
Mud in cooler or compressor jacket.
Machine not clean and clear of oil and moisture.
Ice-making box and system not clean and clear of oil and moisture.

46. Insufficient circulating water.—Feel overboard-discharge pipe to see if it is warm, and look over the side to see if there is an adequate discharge of circulating water. If the overboard-discharge pipe is warm or there appears to be insufficient circulating water, open the valve, putting the flushing or fire pump on the circulating system, and if this does not immediately give sufficient cooling water stop the machine, as its operation for only a few minutes without circulating water will burn up the leathers and cut the compressor and expander valves.

47. Mud in cooler or compressor jacket.—If there is sufficient circulating water, feel the ends of the cooler and the compressor jacket. If either of these is warm, it is due to a deposit of mud. Stop the machine, remove the cooler head, and clean out the cooler. Trouble from this source is likely to be encountered when operating for any length of time in muddy water, as at Shanghai, Mare Island, New Orleans, or the navy yard, New York. Whenever a machine is given a thorough overhaul the cooler should be cleaned out, and if much mud is found the compressor jacket should also be cleaned out by washing out with clean water under a good pressure, or by drawing the liner if the water does not remove the caked mud.

48. Machine or system not clean.—The rise in temperature due to these causes will be gradual and should not occur if the machine has been thoroughly blown down at regular intervals and the ice-making box and system blown out whenever opportunity offered, but if no other cause of the trouble is located the machine should be blown down as previously

described. This should cause the temperature of the cold-air discharge from the expander to come down to the usual reading, and if trouble is still experienced it is due to oil and moisture in the ice-making box and in the system.

49. Loss of pressure, the ratio between pressures remaining correct.—If the machine loses its pressure or refuses to build up the pressure, the ratio between the high and the low pressure remaining correct, the trouble is probably due to one of the following causes:

Leaks around piston or valve rods.
Leaks in cooling coils.
Leaks in ice-making box.
Leaks in system.
Faulty action of primer pump.

50. Locating leaks.—Cut the machine off the system and run it on short circuit; then if the pressure builds up, there are no leaks in the machine.

Put the machine on the ice-making box, and if the pressures are satisfactory the ice-making box is not leaking; then put the machine on the scuttle butt and observe the pressure; then on the cold-storage system and observe pressure. This method will show what part of the installation is leaking.

51. Leaks around piston and valve rods.—Leaks around the piston and valve rods may be discovered by swabbing the rods with oil and watching for air bubbles. If a very little setting up on the gland does not stop the leakage, it is far better to overhaul and renew the packing than to overload the machine with useless friction and run a chance of heating the rod.

52. Leaks in cooling coils.—A pet cock should be installed on the top of the cooler; then, if the machine is running and the cooling coil is leaking, on opening the pet cock air will blow out. If the machine is not running, put an air pressure on the cooling coil, open the pet cock, and close the valves on the sea-water circulating system and air will blow out of the pet cock if the coil is leaking. Using the last method it is possible by trying out to tell whether the main cooling coil or the primer-pump cooling coil, if one is fitted, is leaking.

53. Leaks in ice-making box or system.—Leaks in the ice-making box and the system of piping may be located by covering them with soapy water and watching for air bubbles. Frequently when the ice-making box is leaking it will be found that after running on the ice-making box for some time ice will form over the leaks, stopping them, so that the ice-making box should be examined for leaks soon after turning on the cold air.

54. Faulty action of primer pump.—To determine whether the primer pump is functioning properly, place the hand over the suction and see if the pump is taking air. Feel the primer-pump discharge pipe, and if it is not very warm, the action of the pump is faulty. On the 3-ton machines watch the primer-pump suction valve and see if it is unseating and seating properly. A valve should be placed in the discharge line near the cooler; then, on closing this valve, the relief valve should lift if the primer pump is operating satisfactorily. In case this pump is not operating properly, by closing this valve it is possible on the large machines to overhaul the primer pump-suction valve while the machine is in operation.

55. Loss of pressure, the ratio between the pressures being incorrect.—If the machine fails to maintain the correct pressure and the correct ratio between the high and the low pressure, the trouble is probably due to one of the following causes:

Leaky valves of the compressor cylinder.
Leaky valves of the expander cylinder.
Leaky compressor or expander leathers or packing rings.
Incorrect setting of compressor or expander valves.
Leak in recooler (return-air cooler).

56. Leaky compressor valves.—Stop the machine with pressure on the machine and system, close the valve on the expander inlet, then if the pressures equalize, the valves on the compressor cylinder are leaking.

57. Leaky expander valves.—If the lower pressure is higher than it should be while the machine is in operation, it indicates that the valves of the expander cylinder are leaking.

58. Leaky compressor or expander leathers.—It is difficult to tell whether it is the expander or the compressor leathers or packing rings that are leaking, but, as a rule, the compressor leathers last three or four times as long as the expander leathers. Knowing the time of last renewal of the leathers, it is possible to determine which should be examined first. If there has been any trouble due to an insufficient supply of circulating water, the compressor leathers should be examined first.

59. Incorrect setting of the valves.—The easiest way to determine whether or not the valves are correctly set is to take indicator cards. In fact, incorrectly set valves, leaking valves, and leaking piston leathers can all be located by indicator cards, and no instrument is of more value in operating one of these machines than an indicator. If a machine is in good condition, the indicator card from the expander cylinder will approach very closely to a theoretically perfect card.

60. Leak in recooler.—To determine whether the recooler is leaking, stop the machine with pressure on, then close the valve on the expander inlet and drain the low-pressure air from the system, open the recooler drain cock, and air will blow out if the recooler is leaking. If there is no drain cock on the recooler, one should be installed near the bottom of the low-pressure end for use in draining the recooler and testing it for leaks.

61. Stoppage in discharge pipe from expander.—This will be noticed on the gauge by a drop in pressure on system. To distinguish this trouble from faulty leathers on pistons, open by-pass valve. Should pressures become normal when by-pass is open it will indicate a stoppage in line to cold storage or ice box. Try to run on each separately, and if a normal pressure is not established on either it will indicate a stoppage nearer machine which will most likely be trap choked.

The U. S. S. *New Orleans* had much trouble with the discharge air from expander, due to line freezing up. The most difficult stoppage to locate was that due to the pocket in expander-valve chest freezing up. This pocket is located under slide valve where port connects with discharge outlet. The trouble being in the machine, could not be located by running on the by-pass. It was indicated by a drop in pressure on system and an increase on compressor. The trouble was remedied as follows:

Blow down machine and thaw out, by using hot air from compressor. When hot air has been used about 30 minutes, connect air hose from compressors in engine room to bottom of trap and stop machine. Turn

air into trap, having drains on expander open. Jack machine over a few times. This causes a strong flow of air in opposite directions and dislodges the oil and water collected in discharge port. There was trouble once after this was done, due to the thawing not being complete. After the machine had been in operation about two hours a sudden and almost complete stoppage in discharge took place. To locate the cause the valves of expander were removed. When this was done a piece of ice was found lodged against the outlet.

A complete remedy for this was obtained when the machine was laid up for repairs. The cylinder was removed and a $\frac{3}{8}$-inch drain pipe fitted so as to drain pocket formed by discharge port. Extra heavy nipple was fitted so that there would be no chance of it breaking off in an inaccessible place when cylinder was replaced. A pipe was run to connect, and an angle valve located at after end of cylinder where it was within easy reach. When the machine was in operation this pocket was drained out about twice each watch. No more trouble was experienced with stoppages of freezing line.

This trouble was not caused by allowing water to collect in the small trap on supplementary air line. It was only experienced on the west coast of Mexico, when the machine was being worked to its greatest freezing capacity. The circulating water is not cold enough to cause the moisture in make-up air supply to precipitate in trap. Most of the moisture was deposited in the expander. When a stoppage took place in the freezing line beyond trap it would be found at valve to ice box if machine had been running direct on cold storage, and at valve to cold storage if running on ice box.

The line stopped is easily located. When located, remove bonnet of valve and use a stiff wire or a packing hook to remove ice. It will be found in a mass of small crystals.

62. Gasket for crank end of cooler improperly cut.—The combined trap and cooler for discharge air from the primer pump is located on the head of the cooler nearest the crank end. There is a rib across the inside of this casting extending out flush with the face of the flange so that when in position the newly admitted hot air must pass near the head of the cooler through the space between it and this rib, which space is only the thickness of the gasket. On one ship, in renewing this gasket the new gasket was inadvertently cut with a cross piece in it, which was placed under this rib so that when the machine was assembled it would not build up the pressure because the cross piece prevented the primer-pump air from entering the system. The trouble was finally located by admitting air from the ship's compressed-air line to the primer-pump discharge line and breaking the line from this trap; then, when no air issued from the trap, it was known that the stoppage was in the trap.

63. For suggestions applicable to all types of machines see articles 217 to 222, and for instructions for operation of brine and ice-making systems see articles 223 to 227.

Section 2.—CARBONIC ANHYDRIDE (CO_2) MACHINES.

64. Principle.—In this system the refrigerant is carbon dioxide (CO_2), a colorless, tasteless, odorless, nonpoisonous, nonexplosive gas.

The three principal parts of a refrigerating plant of this type are—

1. The compressor, commonly called the ice machine, in which the gas is compressed.
2. The condenser, in which the compressed gas is cooled by sea water and condensed to a liquid.
3. The cooling coils or brine cooler (also called an evaporator) in which the liquid CO_2 expands into a gas before returning to the compressor and repeating the cycle.

In expanding into a gas in the cooling coils or brine cooler, the heat of vaporization required for this operation is taken from the medium surrounding the expansion coils.

In small plants, aboard ship, the liquid CO_2 is expanded in pipe coils placed in the cold-storage rooms, the gas itself abstracting the heat from the articles in cold storage. This is known as the direct-expansion system.

In larger plants, usually of two tons or more capacity, the liquid CO_2 is expanded in coils in a brine cooler in which calcium chloride brine is cooled. The cold brine is then pumped through the coils in the cold-storage rooms and absorbs the heat from the articles in cold storage. This is known as the brine-circulation system.

On some vessels ice is frozen in the ice-making tank by the direct-expansion system, the expansion coils and the ice cans being immersed in still brine in the tank. On other ships, however, the ice is frozen by means of brine from the system circulated through the coils in the ice-making tank, the coils and the ice cans being surrounded by still brine, as in the direct-expansion system.

Scuttle butts, as a rule, are brine-cooled unless the entire plant operates on the direct-expansion system.

On some ships powder magazines and fruit and vegetable rooms are cooled by air, which is circulated by blowers and passed over the coils in which the CO_2 is expanded.

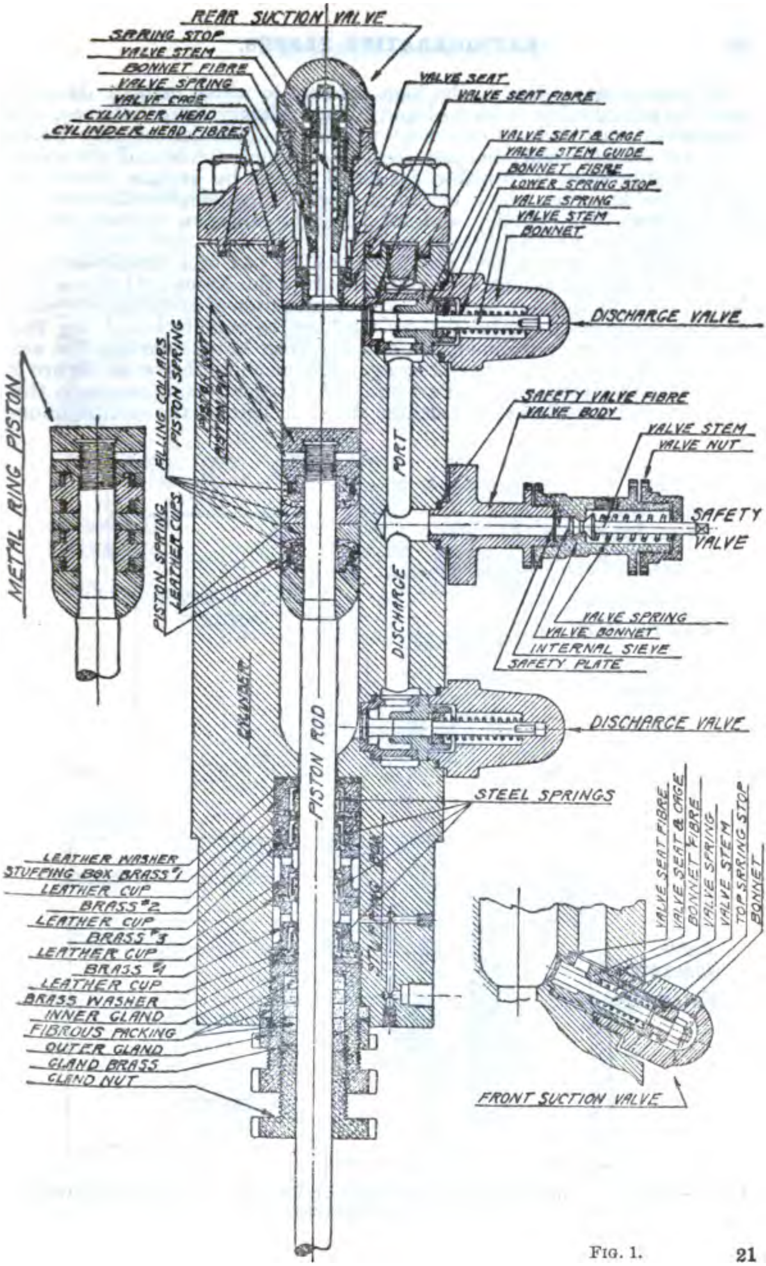


FIG. 1.

Compressor cylinder

65. Compressor.—Due to the high pressure to which carbon dioxide must be subjected in order to liquify it at ordinary temperatures, the compressor must be built extremely rugged, the cylinder usually being of steel or semisteel and other parts being of suitable material and strength.

CO_2 compressors as furnished for naval vessels by various firms are either double-acting, single-cylinder; single-acting, single-cylinder; or single-acting, twin-cylinder; and are driven by either an electric motor or steam engine, usually direct-connected.

The cylinder, piston, and piston-rod stuffing box of a double-acting, single-cylinder compressor as manufactured by the Kroeschell Bros. Ice Machine Co., is shown in figure 1. The construction of compressor cylinders for single-acting, twin-cylinder machines as manufactured by the American Carbonic Machinery Co. and the York Manufacturing Co. are shown in figures 2 and 3, respectively. The machine shown in figure 2 is fitted with a piston-rod stuffing box, the CO_2 gas passing through the cylinders only, while in the machine shown in figure 3 the entire hous-

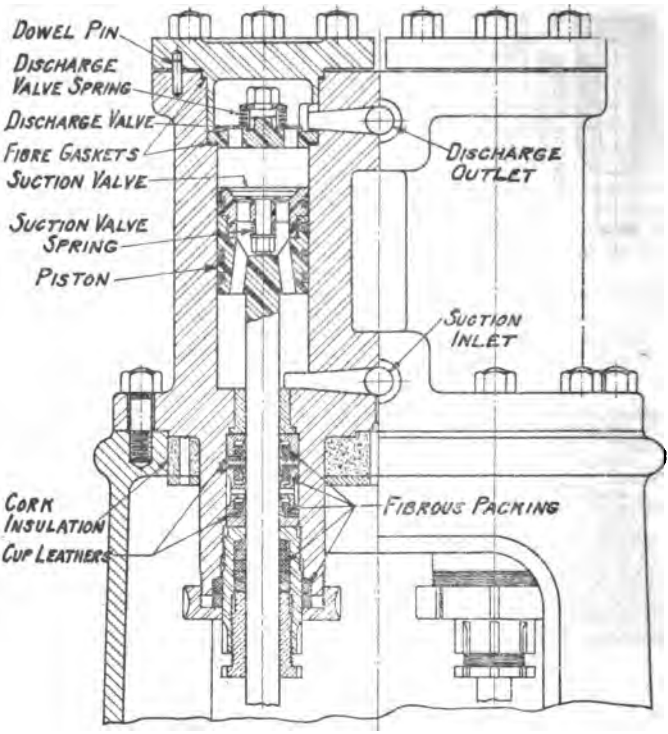


FIG. 2.—Cylinders of American Carbonic Machinery Co. vertical, single-acting, twin-cylinder, CO_2 compressor.

ing is subject to the suction pressure and a stuffing-box is fitted in the opening in the housing for the crankshaft. This crankshaft stuffing box is shown in figure 4.

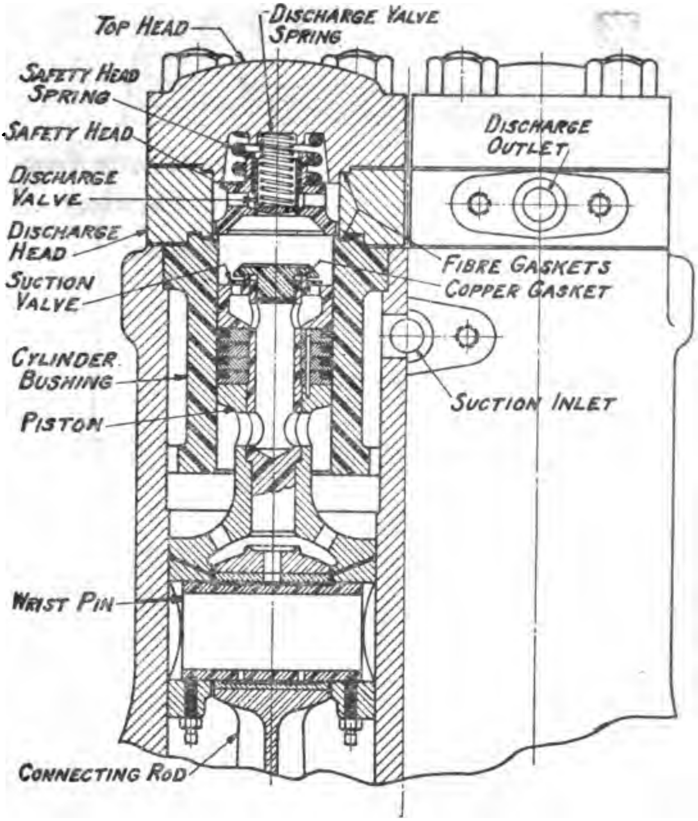


Fig. 3.—Cylinders of York Manufacturing Co. vertical, single-acting, twin-cylinder, CO_2 compressor.

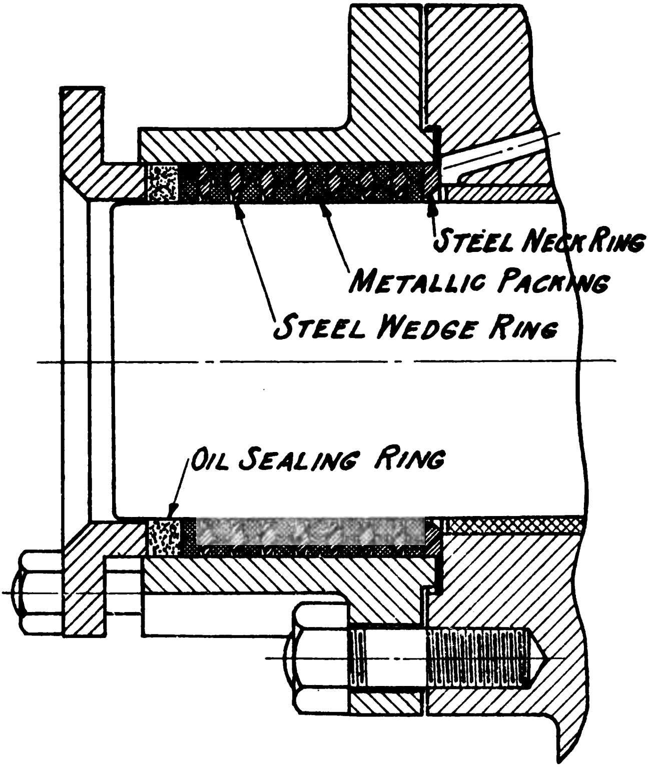


FIG. 4.—Crankshaft stuffing box of York Manufacturing Co. vertical, single-acting, CO_2 compressor.

66. Condenser.—Two types of condensers are in use in CO_2 plants on board ship—namely, the double-pipe type and the shell and coil type.

A double-pipe condenser consists of a tier of tubes connected at the ends by return bends and through which the condensing water flows. Each tube passes through a larger tube, and the discharge gas from the compressor passes through the annular space between the tubes and is condensed by the cooling effect of the condensing water. The condensing water inlet to the condenser is at the bottom, while the gas inlet to the condenser is at the top, the coldest water thus coming in contact with the coldest gas.

The shell and coil, or submerged type of condenser, consists of a cylinder containing a coil through which the discharge gas from the compressor passes and is cooled and liquified by the condensing water. The condensing water circulates through the shell and entirely submerges the coil containing the gas.

A receiver is provided for both types of condensers and acts as a reservoir for the liquified CO_2.

The coil through which the gas passes should be of extra heavy pipe.

67. **Brine cooler.**—Brine coolers on naval vessels are of the submerged type, some being constructed similar to the shell and coil type of condenser, while others consist of a rectangular tank in which the expansion coil is placed, instead of a cylindrical shell.

As in the shell and coil type of condenser, the coil should be of extra heavy pipe.

68. **Brine storage tank.**—On vessels having a brine-circulation system, in which the brine cooler is located in the discharge line from the brine pumps, a brine storage tank in the suction line to the pump is necessary in order to provide a reservoir for the brine and insure a full system and also to purge the brine system of air.

Where the brine cooler is located on the suction side of the brine pumps, no storage tank is necessary, provided the cooler is vented.

69. **Gauges.**—Gauges are installed with each plant which give the pressures in the high-pressure or condensing side and in the low-pressure or evaporating side of the system. Gauges installed with plants furnished by the Kroeschell Bros. Ice Machine Co. and the American Carbonic Machinery Co. have dials graduated to indicate the pressures in atmospheres per square inch, while gauges with plants furnished by the York Manufacturing Co. have dials graduated to indicate the pressures in pounds per square inch. The temperatures of carbon dioxide corresponding to the different pressures are also indicated on the dials of the gauges furnished by all of the above firms.

70. **Starting up a new plant.**—The various parts of a new plant should be cleaned as thoroughly as possible during installation, but some scale, grit, or other foreign matter will probably remain which must be removed from the system if it is to operate efficiently. Also before starting up, the system should be inspected for leaks. This may be done as follows: Connect a drum of carbon dioxide gas to the charging connection and slowly let in sufficient gas to put a pressure on the entire system of about 300 pounds or 20 atmospheres. The drum should be connected to the charging connection with the drum standing on end, valve up. This gas is injected without pumping the air out of the system. The expansion valve should be open in order that the pressure may be equalized throughout the system. All gauges should register the same pressure, if they are correct and the suction, discharge, and expansion valves are open. When the gauges indicate the above pressure, stop charging and go over all joints with a strong solution of soapsuds. Bubbles blown in the soapsuds will indicate the leaks if they exist, and a very bad joint can be found by the whistling sound of the gas blowing out.

In the case of a very bad joint it may be necessary to blow out the greater portion of the gas used for charging, but this is of small consequence, as only about 5 pounds of the gas is required to obtain 300 pounds pressure in small plants.

71. Under no conditions should the plant be put under an air pressure by means of its own compressor, as the heat generated in compressing the air will cause the cylinders to be scored and, if the temperature of the air should reach the flash point of the lubricating oil, an explosion might result.

72. Purging air from the system.—After all leaks have been made tight and the machine has been idle a short time, the air should be purged from the system by turning on the condensing water supply and opening the purge valve, located at the highest point of the condenser. The purge valve should be kept open only so long as the air, which is lighter than CO_2, issues from it. CO_2 issuing from the purge valve will be indicated by a visible vapor or by frost appearing around the opening in the purge valve. This purging operation should be repeated several times, running the machine for short periods between each purging operation in order that the air may be carried from the suction side into the condenser, where it will be trapped by the liquid CO_2 in the receiver.

73. Charging the system.—After the air has been purged from the system, start the machine (see art. 76), and slowly close the expansion valve so as to gradually build up a pressure in the condensing side of the system and reduce the pressure in the suction side. The proper pressures to be obtained are given in articles 79 to 83. While the machine is running, charge additional gas into the system until the proper pressures are obtained. During the operation of charging frost will appear on the lower end of the drum after it is about half emptied, due to the rapid evaporation of the gas, and if charging is continued and moisture is present in the gas the small outlet in the drum valve will freeze up. When frost appears on the drum, close the charging and the drum valves, disconnect the drum, and replace it with a full drum. When the new drum frosts up at the lower end, it should in turn be replaced by a full one and this replacement of drums continued until the first one from which gas was taken is thawed out, after which the drums can again be used in rotation. To remove all of the CO_2 from a drum, the suction valve should be closed while the machine is running with the drum connected for charging. Do not heat the flasks when they freeze up. The fact that the flasks freeze up indicates that moisture is present in the gas and, if a gas drier or moisture absorber similar to that described in article 220 is not installed in the charging pipe care should be taken that the water is not injected into the system. To minimize the amount of water entering the system, the drums should be stored, when not in use, with the valve end down. If water is present in the drum, it will collect in the bottom, as it is heavier than the CO_2. Also by this method of storing the drums the valves may be kept tight against CO_2 liquid, although they might leak gas if the valve end of the drums were up. Before removing a drum for charging it should be raised, still valve downward, and the valve opened sufficiently to blow out any water in the drum. When CO_2 begins to flow the valve should be closed quickly and the drums turned valve end upward. The drum should be kept in this position for at least 10 minutes to enable any water adhering to the sides to drain to the bottom of the drums. After running about 30 minutes, the trap in the suction line should be cleaned out. This is done by closing the expansion valve or the valve between the trap and brine cooler or cooling coils, if one is installed, and allowing this section of piping to be pumped down by the compressor. When as much gas as possible has been removed, close the suction valve and stop the machine. The flange or cap of the trap can then be removed, care being taken to slack back on the nuts slowly in order that the pressure may be relieved gradually and collected grit, dirt, or other foreign matter removed. The suction trap should be cleaned every week for the first month of operation and once or twice a year thereafter unless trouble is experienced with frozen moisture.

74. The crank-case oil in machines having the crank case subject to the suction pressure should be cleaned out after the first six hours running in order to remove the foreign matter deposited at this point.

75. The plant may be considered sufficiently charged when the discharge pressure is correct for the temperatures of condensing water and the proper temperature is obtained in the rooms or brine cooler with frost on the suction line stopping about 1 foot from the machine.

76. **To start the machine.**—Turn on the condensing water and allow it to run long enough to obtain a good discharge before starting any other operation. Open the CO_2 discharge valve full and the CO_2 suction valve about one-half turn. Start the machine and open the suction valve slowly until it is wide open. *Be sure the discharge valve is open before starting the machine;* otherwise a copper disk, which is installed in the safety valve and which has a bursting pressure ranging from 1,400 to 1,700 pounds per square inch, will break and release the gas to the atmosphere. When the pressure has been sufficiently reduced, the spring-loaded valve in the safety valve will close, but the copper disk should be immediately replaced, as the spring-loaded valve may not be perfectly gas tight. If not previously adjusted, the expansion valve which controls the flow of liquid CO_2 from the receiver to the expansion coils in the brine cooler or cold storage rooms should be gradually closed as the temperature of the rooms falls, until a suction pressure is carried which corresponds to the temperatures to be maintained in the rooms as described in paragraph 81.

77. **To stop the machine.**—To shut down close the suction valve, stop the machine, shut off the condensing water supply, and close the discharge valve. Do not close the expansion valve. When the compressor is to be left idle for a long period the gland nuts should be tightened evenly in order to prevent escape of gas through the stuffing boxes. As soon as the compressor is started again care should be taken that the gland nuts are slacked back and adjusted until there is a slight leakage of oil at the stuffing boxes; otherwise the packing will harden and heat, due to lack of lubrication. When the condensers are of the shell and coil type, fitted with steel coils, and a unit is cut out, the coils should be kept fully submerged to prevent deterioration of the coil surface.

78. **Regulating and renewing the oil supply.**—In compressors shown in figures 1 and 2 lubricating oil is pumped into the piston rod stuffing box by a small oil pump driven from the crank shaft, thus lubricating the piston and piston rod. The stroke of the oil pump with these machines is adjustable, and the supply of oil can be regulated by changing the length of stroke. The manufacturers of the machine shown in figure 1 recommend the use of a pump full of oil every six or eight hours. The pump should be refilled before it is empty. The machine shown in figure 3 is fitted with an oil pump driven from the crank shaft which pumps oil into the crank-shaft bearings, from which the oil flows into the crank case and passes through an overflow pipe to a reservoir tank. The pump suction is taken from this tank. The piston, wrist pin, and crank pin in this machine are lubricated by the splash system. To renew the supply of oil, the valve in the overflow pipe should be closed, after which the cover on the reservoir tank may be removed and the oil poured in. When the machine is running, the oil supply is sufficient if it shows at least halfway in the lowest glass in the reservoir tank. Small machines (1 ton or less) of the type shown in figure 3, which are

installed on destroyers, mine sweepers, etc., differ in the oiling system from those just described in that the pump is inclosed in the crank case and the oil is renewed by means of an oil-filling pot. To replenish the oil, the valves on the top and bottom of the filling pot should be closed, the plug in the top of the pot removed, and the oil poured in. Replace the plug, open the top valve wide, and crack open the bottom valves; when the sight glass shows enough oil in the crank case close the bottom valve. The level of the oil in the crank case should show in the glass fitted in the crank case.

Care should be taken that an excess of oil is not pumped into the stuffing boxes on machines so fitted, or that the level of the oil is not carried too high in machines of the closed crank-case type, as this will result in oil being carried over into the system and forming a coating on the inside of the condenser and expansion coils. This coating of oil will reduce the heat transmission in the coils and consequently reduce the capacity of the machine.

79. Pressure.—The discharge pressure required to liquefy the carbon dioxide will vary with the temperature of the condensing water. The temperature corresponding to the discharge pressure of the gas should be from 5° to 15° F. above that of the condensing water leaving the condenser.

80. The suction pressure should be the pressure which corresponds with a temperature of CO_2 about 15° F. below the temperature of the brine leaving the brine cooler, or, if the system is direct expansion, about 20° F. below the temperature to be maintained in the cold-storage rooms. The brine leaving the cooler in a brine-circulation system should be about 15° F. below the temperature to be maintained in the rooms, with a difference in temperature between the incoming and outgoing brine to and from the cooler of 4° or 5° F.

81. In figures 5 and 6 are given temperature-pressure curves of carbon dioxide from which the pressure corresponding to any temperature of the gas likely to be encountered can be read.

The scale of pressures in figure 5 is plotted in atmospheres per square inch and in figure 6 in pounds per square inch, the graduation of the gauges on the machine determining which figure to use.

A curve of temperatures of condensing water plotted against the corresponding pressures of CO_2 is also given. By picking off the temperature of the water, leaving the condenser on this curve and reading down, as indicated by the example shown in dotted lines, the discharge pressure of CO_2 which should be carried, if the plant is operating normally, is given.

Similar curves from which can be determined the CO_2 suction pressure needed to maintain any ordinary temperature in the brine cooler, in brine, or direct-cooled rooms are given.

Examples of the use of these curves are shown by the dotted lines. In the examples in each figure a temperature of condensing water leaving the condenser of 65° F. was assumed. By reading from the intersection of the condensing water curve with the 65° F. ordinate, it will be seen that a discharge pressure of about 59.5 atmospheres, or 870 pounds, will be required. Similarly, assuming a temperature of 15° F. is required in the cold-storage rooms, it will be seen that a suction pressure of about 15.5 atmospheres, or 225 pounds, is required for a brine system or about 18.5 atmospheres, or 270 pounds, for rooms cooled by the direct-expansion

system. Likewise, the temperature of brine required for a temperature of 15° in the rooms will be 0°.

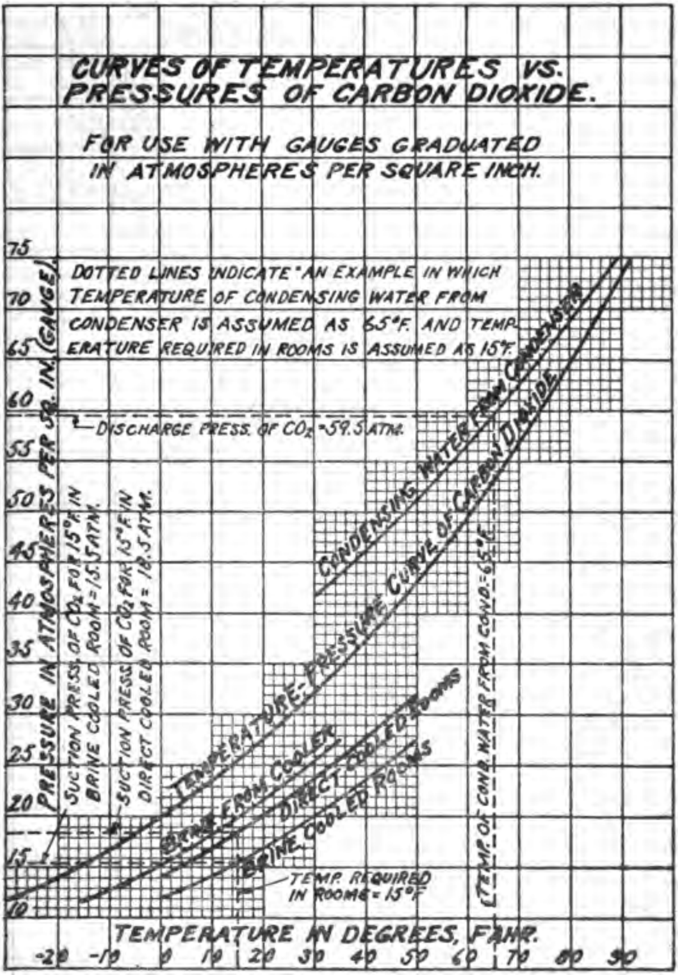
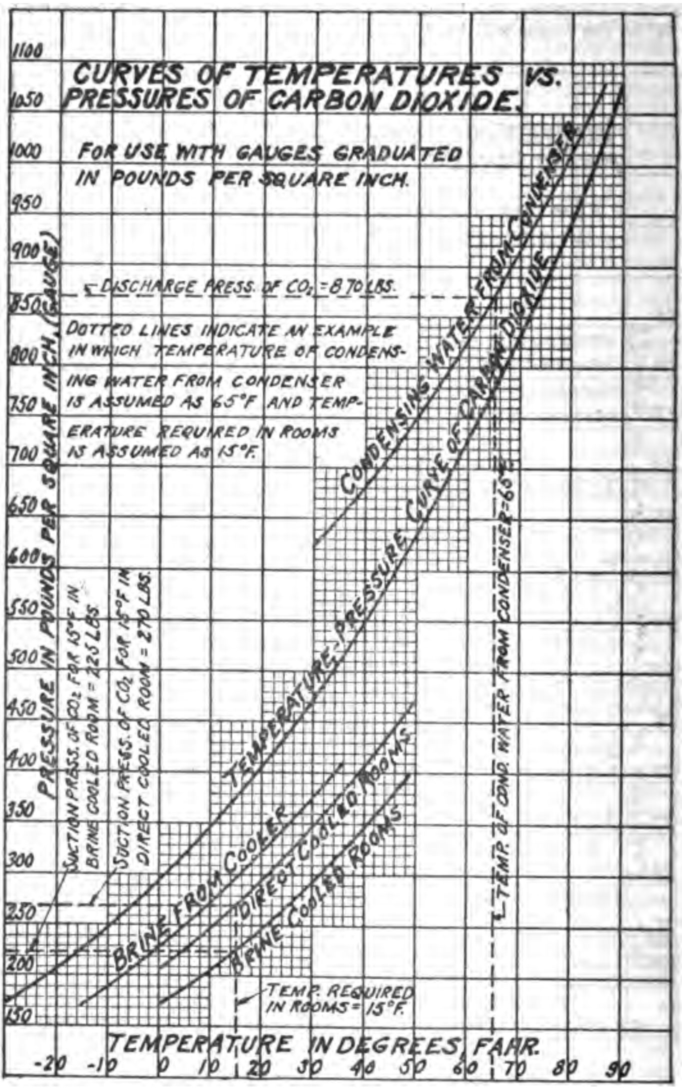


FIG. 5.



CURVES OF TEMPERATURES VS. PRESSURES OF CARBON DIOXIDE.
FOR USE WITH GAUGES GRADUATED IN POUNDS PER SQUARE INCH.
DISCHARGE PRESS. OF CO_2 = 870 LBS.
DOTTED LINES INDICATE AN EXAMPLE IN WHICH TEMPERATURE OF CONDENSING WATER FROM CONDENSER IS ASSUMED AS 65°F AND TEMPERATURE REQUIRED IN ROOMS IS ASSUMED AS 15°F.
PRESSURE IN POUNDS PER SQUARE INCH, (GAUGE)
SUCTION PRESS. OF CO_2 FOR 15°F IN BRINE COOLED ROOM = 225 LBS.
SUCTION PRESS. OF CO_2 FOR 15°F IN DIRECT COOLED ROOM = 270 LBS.
CONDENSING WATER FROM CONDENSER
TEMPERATURE-PRESSURE CURVE OF CARBON DIOXIDE
BRINE FROM COOLER
DIRECT COOLED ROOMS
BRINE COOLED ROOMS
TEMP. OF COND. WATER FROM CONDENSER = 65°F
TEMP. REQUIRED IN ROOMS = 15°F.
TEMPERATURE IN DEGREES, FAHR.
1100
1050
1000
950
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
-20
-10
0
10
20
30
40
50
60
70
80
90

FIG. 6.

82. Variations from pressures given in figures 5 and 6 may occur in actual practice due to differences between the amounts of condensing water and brine actually circulated and the amounts on which the curves are based, but if the plant is operating normally and efficiently the pressures should be reasonably close to the pressures in figures 5 and 6, which correspond to the temperatures of condensing water and cold-storage rooms.

83. As the critical temperature of carbon dioxide is about 88° F., above which temperature it can not be liquified by compression, the amount of condensing water circulated should be increased as warmer waters are encountered in order that the differences between the temperatures of the water and CO_2 in the condenser may be reduced as much as possible. This difference should be not over 5° F. when the temperature of the water is 80° F. or above.

84. **Causes of inefficient operation.**—If the machine is not working properly in that the correct temperatures of brine or rooms or the correct pressures of CO_2 can not be obtained, it may be due to one of the following causes:

(*a*) Shortage of gas in the system.
(*b*) Leaking compressor valves.
(*c*) Defective packing.
(*d*) Moisture in system.
(*e*) Dirt and excessive oil in system.
(*f*) Leak in system.

85. **Insufficient gas in system.**—If the gauge in the high-pressure side of the system records an abnormally low discharge pressure below that corresponding to the condensing water temperature as given in figures 5 and 6, while the suction pressure is correct, and further closing of the expansion valve increases the discharge pressure but results in an abnormally low-suction pressure, the supply of gas in the system is insufficient. This trouble is also indicated by the absence of frost on the machine suction line. A drum of carbon dioxide should be connected to the charging valve and sufficient gas allowed to enter the system to restore the pressures to normal. *Any machine will develop only a fraction of its cooling capacity if the system is short of gas.* An overcharge of gas will be indicated by an increase in the discharge pressure over that corresponding to the condensing water temperature, and is caused by using warm condensing water after having recently charged the system when using cool condensing water—conditions which would arise upon entering the Gulf Stream from surrounding cooler waters. An overcharge within reasonable limits is conducive to high efficiency in operation, and if a high discharge pressure is due to this cause alone plant should not be disturbed.

86. **Leaking compressor valves.**—In a single-acting twin-cylinder machine leaking valves are indicated if the discharge end of one cylinder is cold while the discharge end of the other cylinder is warm. A leaking or sticking valve will also be indicated by uneven vibration of the pressure gauges. In a double-acting single-cylinder machine, in which a discharge valve is leaking, the valve having the hottest cap is the one that is leaking, while if a suction valve is leaking the gas can be heard hissing through on the discharge stroke if the ear is placed close to the bonnet.

87. To overhaul the valves, the compressor should be shut down and the suction and discharge stop valves at the compressor closed. The compressor valves should then be removed and both valves and seats cleaned of oil, scale, chip, or other foreign matter and, if necessary, reground.

88. In machines with valve seatings making double joints see that both the bonnet joint ring (fiber or copper) and the valve joint ring are equally compressed. This must be carefully looked after or a leaky joint will ensue. If the impression on the two rings is unequal, add paper washers under the lighter one until the impression is equalized. Leaking at the bonnet joint will indicate itself outside, but a leak at the valve-seat joint will not be perceptible except in reducing the work done by the machine. Compressor suction and discharge valves should be examined at least every six months and replaced or reground, if necessary.

89. **Worn or defective packing.**—If difficulty is experienced in maintaining the correct pressures and the compressor valves are not leaking or the system is not short of gas, the trouble is probably due to worn piston packing or rings. If found necessary after examination, the piston leathers or rings should be renewed. It should not be necessary to renew cast-iron piston rings oftener than once every six months, while piston leathers, if fitted, usually need renewal about once a week.

In case there is a leakage of gas, the piston rod or crank-shaft packing should be examined and renewed if found necessary.

90. Lubrication of the cylinders of open-type compressors fitted with piston-rod stuffing boxes is accomplished by feeding the oil into open spaces or lanterns in the stuffing boxes, from which point it is carried into the cylinders. In compressors having closed crank cases, the oil which is pumped into the bearings also lubricates the stuffing boxes on the crank shaft. In each type of machine, the oil forms a seal to assist in preventing leakage of gas around the piston rod or crank shaft. It is essential that the packing in the stuffing boxes be well lubricated at all times while operating, and to insure this the gland should be adjusted so that there is always a slight leakage of oil at the outside of the stuffing box.

91. **Moisture in system.**—Moisture enters the system with the CO_2 gas during charging, and its presence results in the expansion valve and small pipes freezing up. A freeze-up will be indicated by an abnormally low suction pressure, if it occurs in the suction line between the condenser and the gauge connection. A freeze-up of the suction trap will cause a rise in the suction pressure if it is located between the gauge connection and the compressor.

92. To thaw and remove water from the system, open all valves, including the expansion valve, as wide as possible, run the machine, and circulate the combined liquid and gas through the system without any expansion. This warms up the entire system, thaws the ice, and allows the water to be carried over into the traps, from which it can be drained.

A gas drier or moisture absorber installed in the charging pipe will prevent moisture entering the system while charging. A gas drier suitable for use with carbon dioxide is described in article 220.

93. Care in storing and handling drums while charging, as described in article 73, will also minimize the amount of moisture entering the system.

94. **Dirt and excessive oil in system.**—Dirt and other foreign matter should be removed from the system when first started up and after every overhaul; otherwise the compressor valves will become scored and leak.

95. Excessive oil in the compressor will be carried over into the expansion coils, in which it will congeal and form a coating on the inside of the pipes and, as has been explained, reduce the refrigerating capacity of the machines.

96. A fluctuating suction pressure, such as a gradual lowering of the pressure without any change in the discharge pressure, followed by a rapid or gradual rise in the suction pressure without apparent cause, indicates the presence of oil or other foreign matter in the system.

97. By opening the expansion valves and circulating warm gas for a short time the oil or other matter may be forced into the traps, the drain valves on which should be opened at frequent intervals until the system is clear.

98. If this does not liberate the foreign matter, the condensing water supply may be reduced or shut off entirely for a short period of time only in order that the hot gas may circulate through the system and melt the congealed oil, which will then be deposited in the traps. If it is necessary to shut off the condensing water, care should be taken that the pressure does not become excessive.

99. Leak in system.—A leak in the system will be indicated by a drop in suction and discharge pressures, after sufficient gas has been charged into the system. If the leak is in an exposed part of the system, it can be found by examining all joints with soapy water or a lighted candle.

100. If a leak exists in a tube of a double-pipe condenser or in a coil of a shell and coil type condenser or brine cooler, it is more difficult to detect. One method of finding such a leak in double-pipe condensers is to close the main supply and discharge valves in the condensing water line and then close the water valves at the top and bottom of all except one condenser section. Remove the bonnet of the top valve of that section, and if CO_2 is escaping in that section it will bubble out through the water. If there is no evidence of a leak, the test can be carried out with the other condenser sections.

101. The same procedure can be followed in detecting leaking coils in shell and coil type condensers and brine coolers.

102. Another method which can be adapted to all types of condensers and brine coolers is to insert a pressure gauge in the thermometer fitting in the condensing water or brine lines after closing the supply and discharge valves in the line. In case a leak exists, the pressure recorded on the gauge will rise, due to the escape of carbon dioxide into the water or brine system.

103. The exact tube which is leaking in a double-pipe condenser can be ascertained in this manner by removing the return bends and closing the ends of the tube being tested with temporary plugs or caps into one of which the gauge can be screwed. The tube on which the gauge shows a rise in pressure is leaking and should be replaced.

104. To insure against leaks occurring in pipe joints, it is essential that care be exercised in making up these joints. Figure 7 shows a flanged pipe joint, fiber-gasket type, as used with apparatus furnished by the American Carbonic Machinery Co. and Kroeschell Bros. Ice Machine Co. Figure 8 shows a flanged pipe joint, copper-gasket type, as used with apparatus furnished by the York Manufacturing Co.

In making up both types of joints the ends of the pipes should be faced or filed perfectly square. In the joints shown in figure 7 the ends of the pipes should project not more than $\frac{1}{32}$ inch beyond the faces of the flanges, while in the joint shown in figure 8 the pipe screwed in the plain flange should project $\frac{1}{4}$ inch, and the pipe in the female flange should be flush with the face of the flange or project very slightly.

The flanges should be a fairly tight fit on the pipe, but the threaded portion need not be gas-tight, as the sealing effect is made by the gasket between the ends of the pipes.

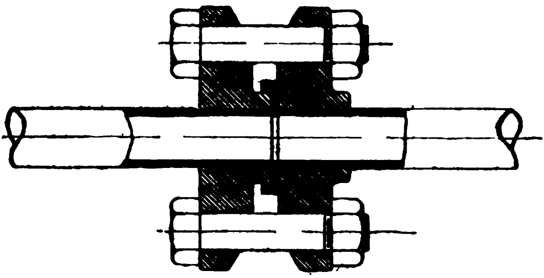


FIG. 7.—Complete flanged pipe coupling, fiber gasket type.

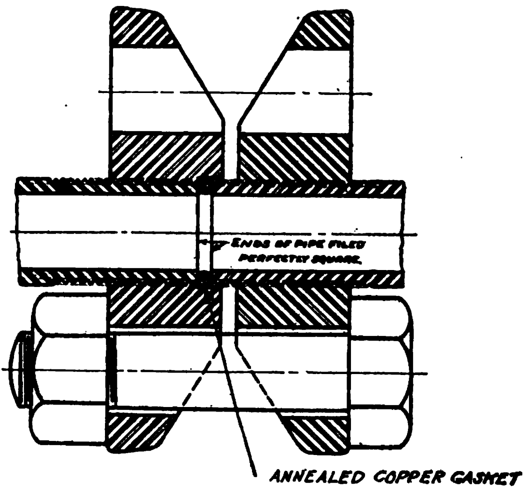


FIG. 8.—Complete flanged pipe joint, copper gasket type

Before inserting a gasket the pipe ends should be cleaned of dirt or scale which may have become lodged on them. The joints should be drawn up evenly and should be followed up occasionally, especially during the first few weeks of operation.

105. A usual place for leaks to occur is around the CO_2 stop valve stems, and a careful inspection of these valves should be made from time to time.

106. To assist in detecting leaks, a small quantity of ether or oil of peppermint can be placed in the charging pipe and injected into the system with the CO_2 gas about once a month. This will render the gas in the system odorous, and the fact that a leak exists can be determined by the sense of smell.

107. To pump down a section of the plant.—The procedure to be followed in pumping down a section of the plant will vary with different installations, but it is possible to transfer the greater portion of the gas from any one condenser to another, if more than one is installed, and from the brine cooler or cooling coils in the rooms, in a direct expansion plant, to the condensers, by proper manipulation of the valves.

When pumping out any portion of the plant, do not pump down below 120 pounds or 8 atmospheres. Allow the gas remaining in the section to be opened up to blow to the atmosphere.

108. Use of trap drains.—The oil traps on the gas line between the compressor and the condenser and the return trap on the suction line should be blown out once or twice a day. If the oil expenditure is very well regulated, the traps need not be blown oftener than once a day. Great care should be exercised in blowing traps so as to remove all the oil with the least loss of gas. The drain valve should be opened and then closed after a very short interval to allow the oil to again settle to the bottom. The opening and closing should be repeated until all of the oil is removed. When opportunity offers, and especially during overhaul, remove the covers from the traps and clean them thoroughly. When the plant is new the traps should be cleaned frequently.

109. Opening the compressor or piping.—Before opening the compressor for examination close the suction and discharge stop valves tight. The joint between the head and cylinder should be opened by slacking back on the nuts slowly in order that the gas may escape gradually. Likewise, in opening joints in the piping or removing valve bonnets the gas should be allowed to leak out before completely opening the joint or valve.

110. For suggestions applicable to all types of machines, see articles 217 to 222, inclusive, and for instructions for operation of brine and ice-making systems, see articles 223 to 227, inclusive.

Section 3.—ETHYL CHLORIDE MACHINE (CLOTHEL CO.).

111. Refrigerant.—The refrigerant used with this machine is ethyl chloride (C_2H_5Cl), a very stable chemical. It has no reaction with air or water, so no chemical change will take place in case either of these enter the system. (Every precaution should be taken, however, that air or water is excluded from the system in order that the efficiency of the machine will not be impaired.) It has no effect on metals, thus permitting a large choice in the materials to be used in the construction of the machines and piping. It is neither poisonous nor has it an obnoxious odor. It has decided anæsthetic properties, producing total anæsthesia if inhaled

in sufficient quantity. It is not explosive, but is inflammable when sufficient vapor is present in the air and exposed to a naked flame or electric spark. In handling or testing for leaks in the apparatus, care should, therefore, be exercised that no flame or electric apparatus liable to produce a spark is in the immediate vicinity.

112. Principle.—The principle upon which the system works is the same as that of the CO_2 plant previously described. Ethyl chloride, however, will liquefy under much lower pressures than either carbon dioxide or ammonia and the apparatus is, therefore, designed for these lower pressures, the maximum pressure in the condensing or high-pressure side of the system being about 25 pounds per square-inch gauge with a temperature of outgoing condensing water of 100° F.

113. Description of apparatus.—The ½-ton equipments of this type which have been installed in naval vessels have been modified at various times until there are three distinct arrangements of apparatus of this size, in each of which there are variations in the arrangement or design of certain parts of the equipment.

The first equipments of this type to be furnished were mounted on the side of the refrigerator box, and a diagrammatic layout of the apparatus and piping is shown in figure 9. The chemical in a gaseous state is compressed and discharged by a rotary compressor through a lubricant separator into a vertical condenser, in which it is condensed to a liquid state by the cooling effect of the circulating water. From the condenser the liquid ethyl chloride passes to the lubricant-accumulating tank and then to a ball-float trap, in which the flow of the liquid into the low-pressure side of the system is controlled by a float valve.

From the trap the ethyl chloride, in a gaseous state, passes through the catchall tank to the expansion grid or cooler, and, having extracted heat from the contents of the refrigerator box, passes to the suction side of the compressor and the cycle is repeated.

The lubricant trapped in the separator is drained to the condenser and thence to the lubricant-accumulating tank.

Lubricant is charged into the system by means of a hand pump which discharges into the drain line from the separator.

A suction strainer and vacuum gauge is fitted in the compressor suction line, and a pressure gauge is fitted in the compressor discharge line.

The layout of the first equipments to be furnished mounted on top of the refrigerator box differed from that described above in that a horizontal condenser was used instead of a vertical one and the catchall tank was omitted, the refrigerant expanding directly from the trap to the expansion grid. Also the separate lubricant line from the condenser to the accumulating tank was omitted. This layout is shown diagrammatically in figure 10.

Further modifications in later equipments were the substitution of a differently constructed separator and the omission of the lubricant-accumulating tank. Also the separator was relocated below the condenser, the discharge gas from the compressor passing directly to the condenser and the lubricant being drained direct to the compressor from the separator. A diagrammatic layout of this equipment is shown in figure 11.

114. Compressor.—The compressor used with the Clothel system is of the rotary type and is shown in figure 12. It consists of a cylindrical rotor installed eccentrically in its casing and fitted with four blades.

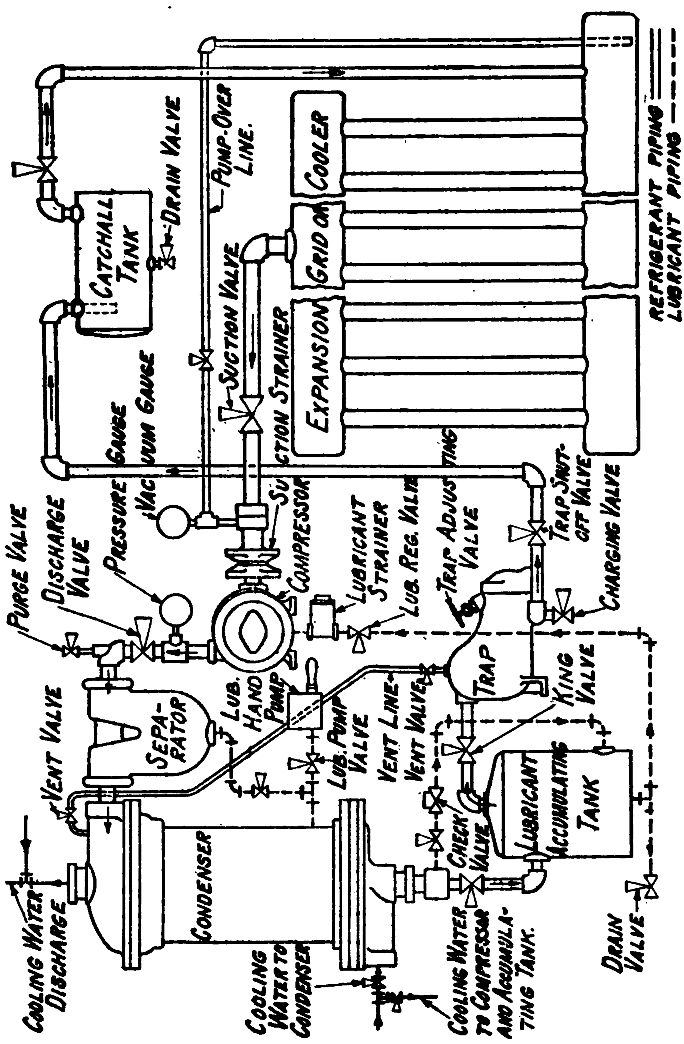


Fig. 9.—Diagrammatic arrangement of ethyl chloride refrigerating equipment.

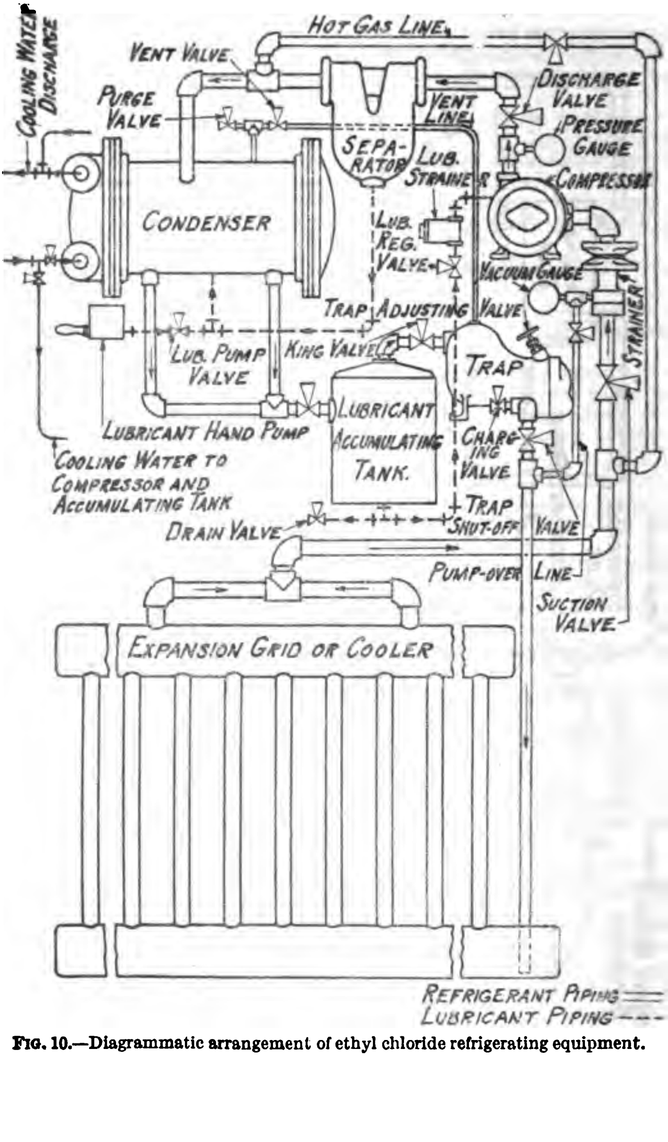


Fig. 10.—Diagrammatic arrangement of ethyl chloride refrigerating equipment.

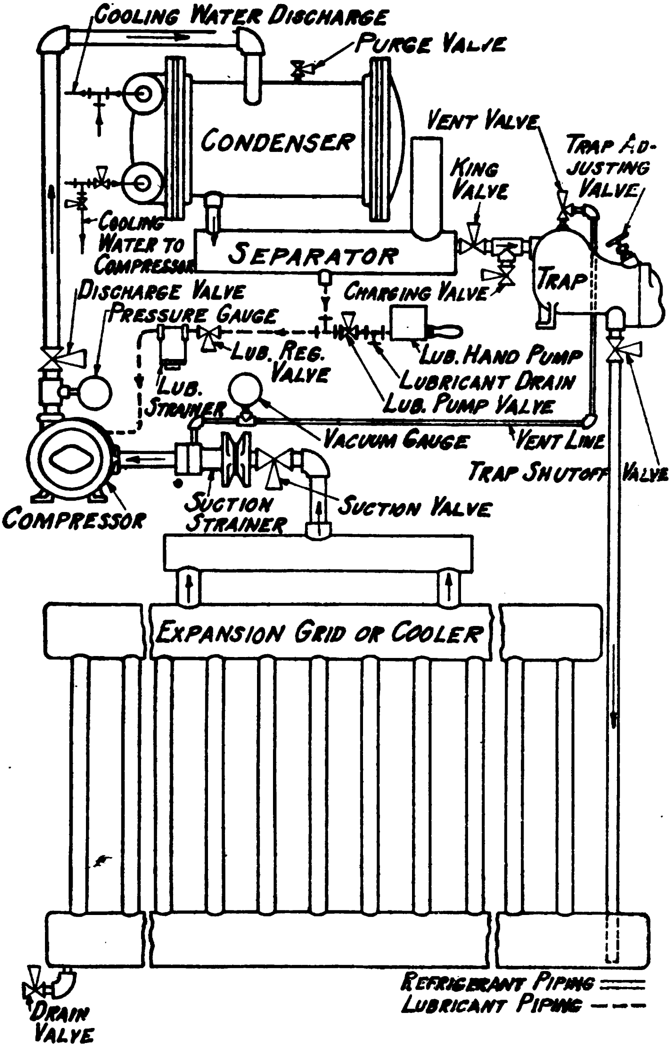


FIG. 11.—Diagrammatic arrangement of ethyl chloride refrigerating equipment.

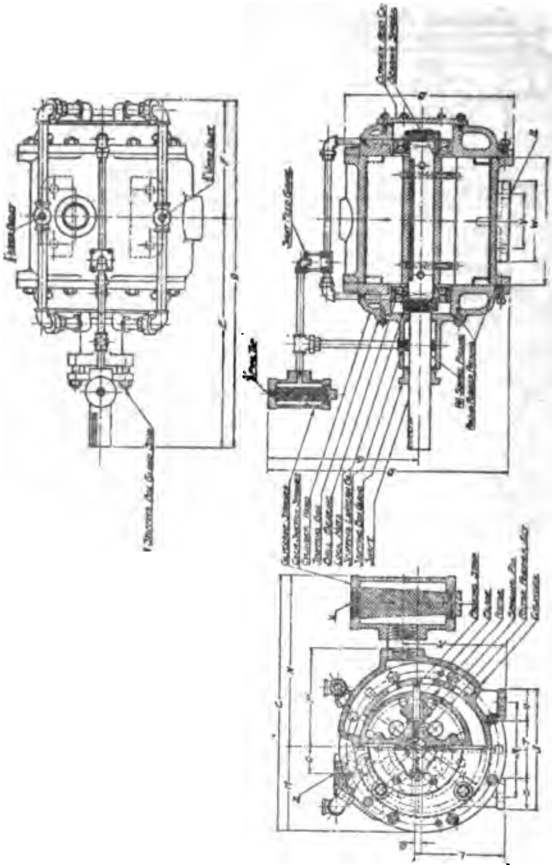


FIG. 12.—Constructional Details of Rotary Compressor.

These blades are free to move radially in slots milled in the rotor and are held apart by spacing pins between opposite blades. Half-round packing strips are fitted to the outer edges of the blades and make contact with the walls of the casing.

The gas is drawn in and discharged through ports in the walls of the casing by the revolving rotor, which can be either electric or steam driven.

The compressor heads are cored and the hollow portions connected to the condensing water supply to avoid undue heating of the compressor parts.

The compressor is lubricated by glycerine, which should be chemically pure and free from water or other adulterants, fed through a strainer and

a sight feed gauge into the compressor bearings. A connection is also fitted from the lubricant line to the shaft stuffing box in which the lubricant enters a lantern gland and acts as a seal. Glycerine is the only lubricant which can be used with this type of machine.

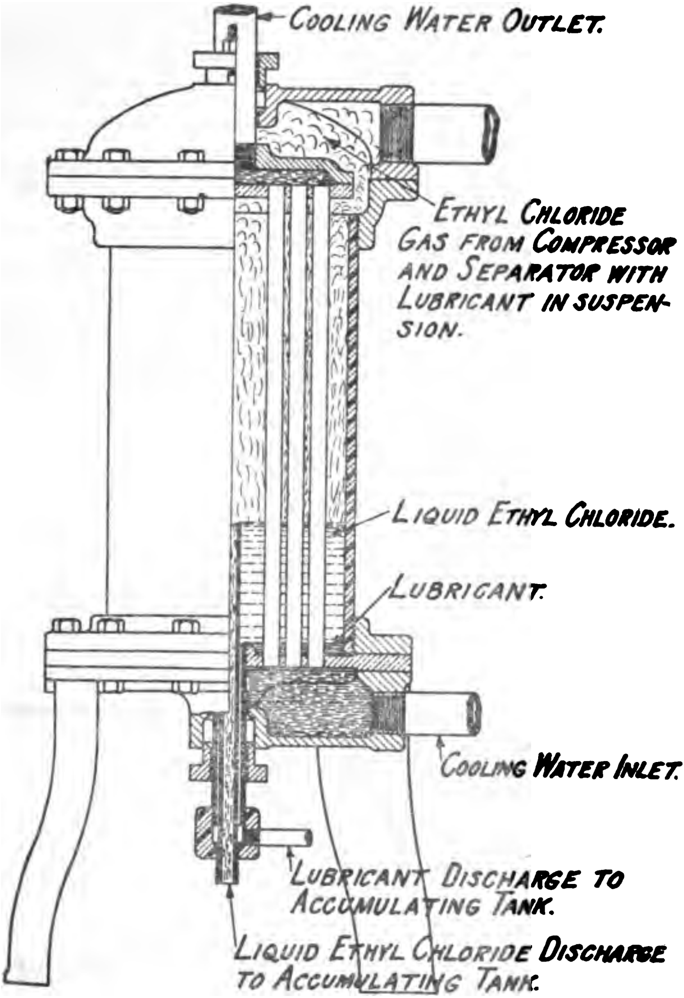


FIG. 13.—Vertical condenser.

115. Condenser.—With ½-ton compressors mounted on the side of the refrigerator box, a vertical ethyl-chloride condenser was furnished. The construction of this condenser is clearly shown in figure 13. The cooling water enters the bottom head, passes through the tubes, and leaves the condenser through a pipe screwed into the top tube-sheet head and which passes through a stuffing box in the top condenser head. The ethyl chloride which has been discharged from the compressor enters the top head and circulates around the tubes, the condensed refrigerant collecting at the bottom of the condenser. Some lubricant is carried over into the condenser and, being heavier than the refrigerant, falls to the bottom of the condenser and is drawn off to the accumulating tank as shown in figure 13.

The liquid ethyl chloride is discharged to the lubricant-accumulating tank through a pipe extending into the condenser about 5 inches above the bottom tube sheet.

With ½-ton compressors mounted on top of the refrigerator box a horizontal condenser is furnished. This condenser is similar in construction to the ordinary steam surface condenser, the cooling water making six passes through the tubes.

116. A further modification which has been made in the horizontal condenser consists of the use of U-tubes instead of straight tubes, which eliminates one tube sheet and one condenser head, the condenser being similar in construction to the brine cooler shown in figure 19. The cooling water makes four passes through the tubes in this condenser.

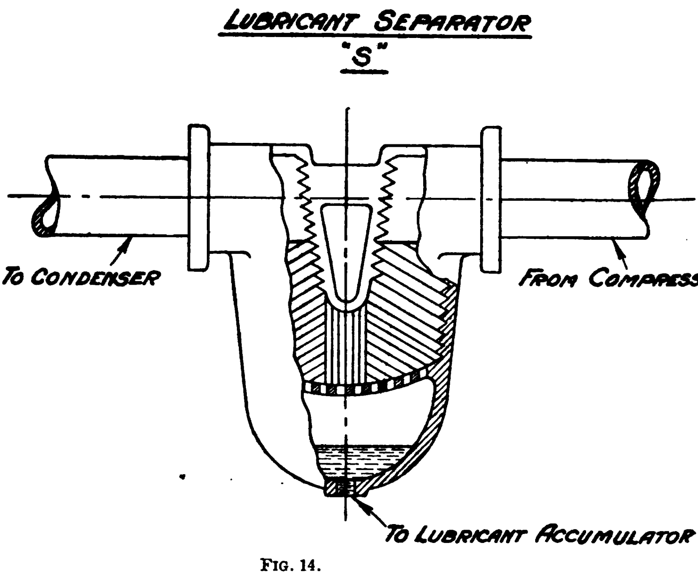


FIG. 14.

117. Lubricant separator.—As a considerable amount of lubricant is contained in the discharge gas from the compressor, a separator is placed in the high pressure side of the system. Two types of separators have been furnished, they being shown in figures 14 and 15. The separator shown in figure 14 is installed in the discharge line between the compressor and condenser. The separator shown in figure 15 is installed below the condenser and the mixture of refrigerant and lubricant passes through the condenser before entering the separator. The type of separator shown in figure 15 is the one at present being furnished with Clothel installations.

118. Lubricant-accumulating tank.—This tank contains a coil through which cooling water from the condensing water supply line is circulated and acts as a receiver or reservoir for the liquid ethyl chloride and the lubricant.

With installations as shown in figure 9, the lubricant, being heavier, enters near the bottom of the tank and is returned to the compressor through a connection in the bottom head. The liquid ethyl chloride passes to the ball-float trap through a connection in the top head. A drain connection is fitted to the lubricant outlet in the bottom head. This tank is shown in figure 16. With installations as shown in figure 10, the lubricant and ethyl chloride pass from the condenser to the accumulating tank through a common pipe, and the lubricant falls to the bottom. The lubricant connection on the side of the tank near the bottom is either plugged or fitted with a valve and used as a drain.

This tank is omitted from the latest equipments.

119. Ball-float trap.—The flow of the refrigerant from the high-pressure side to the low-pressure side of the system and its expansion from a liquid to a gaseous state takes place through a trap and is controlled by a valve, operated by a ball float. This trap is shown in figure 17. The discharge valve, which closes against the pressure, is opened by the ball float when the level of the liquid refrigerant in the trap rises and is closed by the weight of the float when the level of the refrigerant falls. The hand wheel located on top of the discharge end of the trap controls the trap-adjusting valve and is used to hold the discharge valve open when necessary, but should not be used to control the operation of the discharge valve when the system is in use and is operating properly. The level of the liquid refrigerant in the trap at which the discharge valve will open can be regulated by adjusting the length of the discharge valve stem. This is done by removing the head of the trap (having first emptied the system of refrigerant as described in articles 137 to 141, inclusive), slacking back the lock nut on the valve stem, and screwing the stem in or out of the fitting to which it is attached. By screwing the stem into the fitting—that is, reducing its length—the level at which the valve will open will be raised, while the reverse will be the case if the valve stem is lengthened. Care should be taken not to bend the valve stem and to tighten up the lock nut on the valve stem after the adjustment has been made.

120. A vent line is run from the top of the trap to the condenser in installations arranged as shown in figures 9 and 10 and to the compressor suction strainer in installations arranged as shown in figure 11. The purpose of this vent pipe is to release any gas which may collect in the trap. The valve in this vent line in installations shown in figures 9

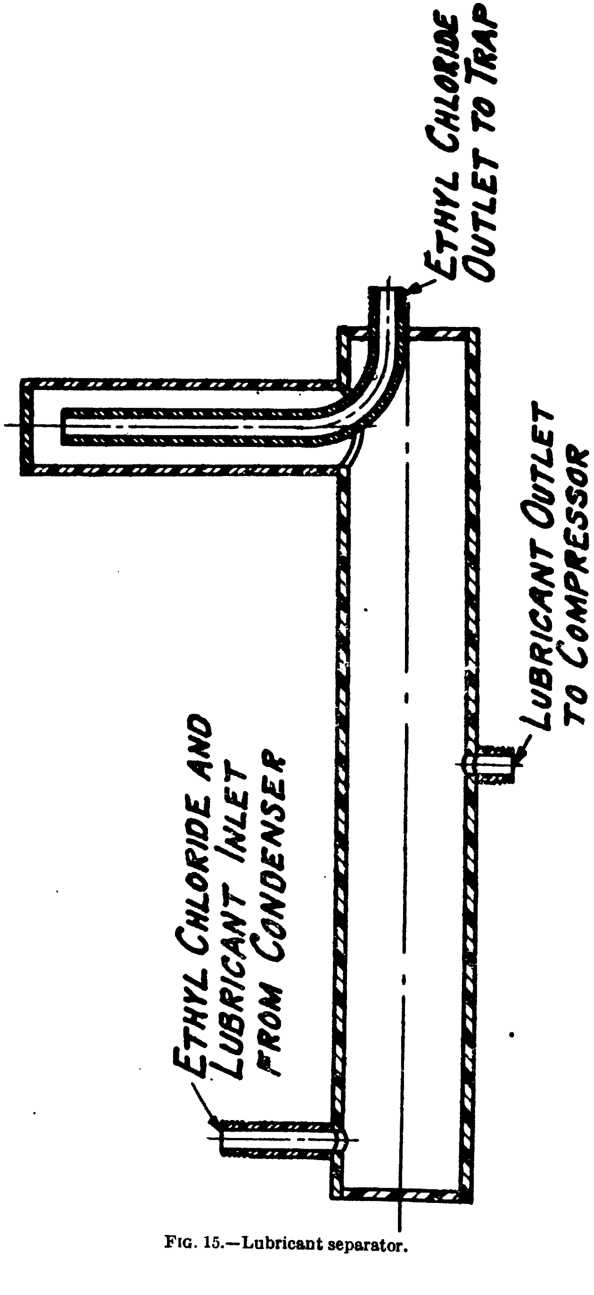


FIG. 15.—Lubricant separator.

and 10 should be wide open when operating, while in installations shown in figure 11 this valve should be open one-quarter of a turn.

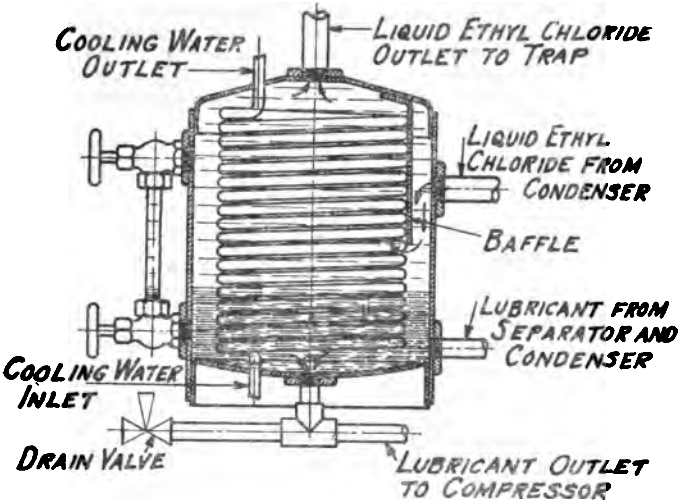


FIG. 16.—Lubricant accumulating tank.

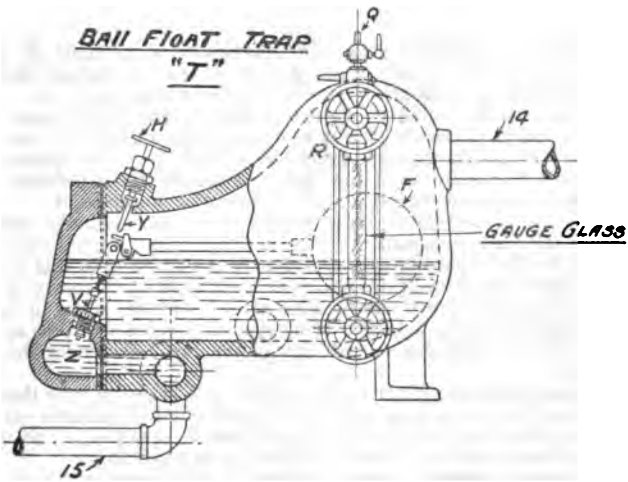


FIG. 17.

121. Catchall tank.—This tank has been omitted from later installations of ethyl-chloride machines, it having been furnished only with ½-ton equipments mounted on the side of the refrigerator box. Its purpose is to entrap any lubricant or foreign matter which may be carried over by the refrigerant and which was not removed in the separator, condenser, lubricant-accumulating tank, or trap. The construction of the catchall tank is shown in figure 18. The tank should be drained at frequent intervals in order that the foreign matter will not be carried over into the cooler.

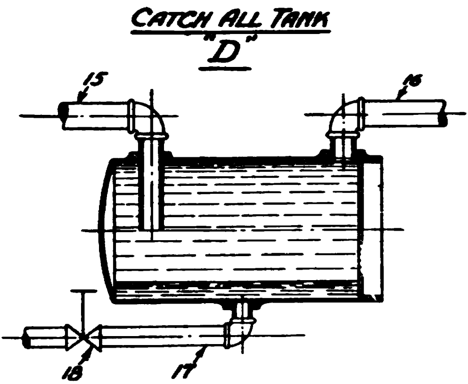


FIG. 18.

122. Cooler or expansion grid.—In ethyl-chloride systems of ½-ton capacity, as installed in naval vessels, the refrigerant is expanded directly into a cooler or expansion grid contained in the refrigerator box. This cooler is built up of welded wrought-iron pipe and is of the same construction for all equipments of this size except for changes in connections. The changes are shown in figures 9, 10, and 11. After abstracting the heat from the contents of the box, the gas in the expansion grid passes to the compressor and the cycle of operation is repeated.

123. Brine cooler.—Where larger units than ½-ton capacity are installed and the cold-storage rooms are cooled by brine, a brine cooler is substituted for the expansion grid and the gas is expanded in this cooler, extracting heat from the brine, which is circulated by a rotary pump driven from the compressor shaft. The brine cooler is shown in figure 19. The apparatus used with the brine system is similar to that shown in figure 11, except for the substitution of the brine cooler for the expansion grid.

124. To start machine (refer to figs. 9, 10, and 11).—Be sure that all valves in the refrigerant lines, except the suction and discharge valves, are open and the float valve in the trap is free to operate. (The trap-adjusting valve should be screwed back as far as possible.)

Open discharge valve and water-supply valve to compressor and condenser and start the machine.

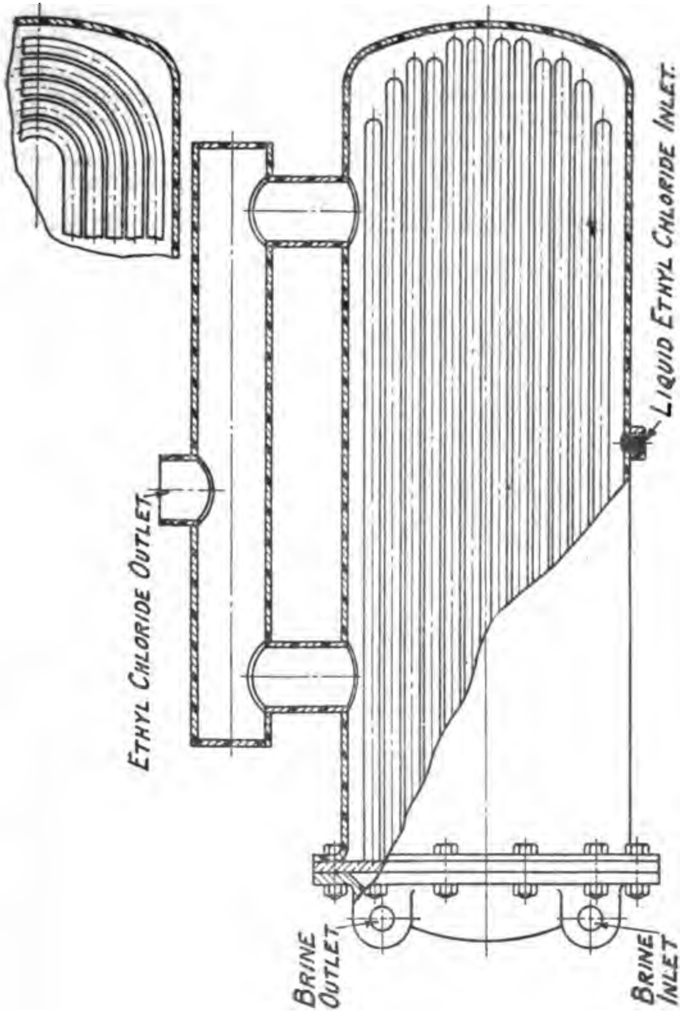


FIG. 19.—Brine cooler.

Open the suction valve and lubricant valve and regulate the supply of lubricant until a steady stream flows through the sight feed gauge.

125. In order to obtain a flow of water through the condenser it may be necessary to vent out the air through the air-vent cock on the condenser head. The cooling water to the compressor should be regulated so that the compressor heads are kept just lukewarm under ordinary conditions. The cooling-water valves should always be opened before starting the machine for any purpose whatever.

126. Pressures.—After the machine is started, the flow of condensing water should be regulated to obtain a discharge pressure approximately equal to the pressure corresponding to the temperature of the water leaving the condenser as read from the condensing water curve in figure 20.

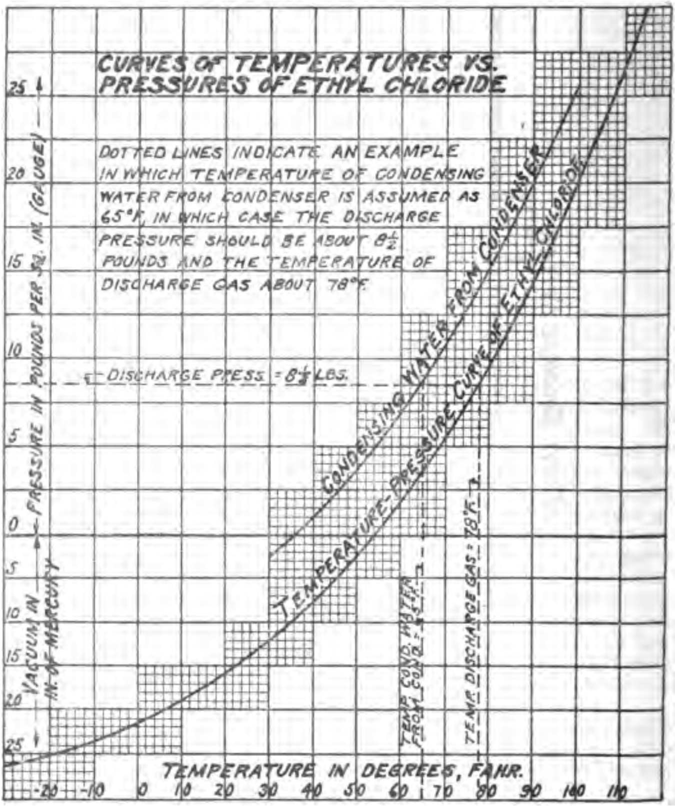


FIG. 20.

127. An example in the use of this curve is shown by the dotted lines, in which the temperature of the water leaving the condenser is assumed as 65° F. By reading from the intersection of the ordinate marked 65° with the condensing water curve, it will be seen that the discharge pressure should be 8½ pounds. The discharge pressure for any temperature of condensing water likely to be encountered may be found in a similar manner. It is not necessary that the discharge pressure be exactly as read from the curve, but it should be reasonably close.

128. The vacuum carried in the low-pressure side of the system depends entirely on the amount of work the machine is doing and can not be regulated as in other types of plants fitted with expansion valves. The temperature-pressure curve of ethyl chloride in figure 20 gives the temperature of the gas corresponding to any vacuum of 26.5 inches of mercury or less, as well as the temperatures corresponding to pressures up to 30 pounds per square inch gauge, and the temperature of the gas in the cooling coils or brine cooler will correspond on this curve to the reading of the vacuum gauge.

129. To stop machine.—Close the lubricant valve about *five minutes before* stopping machine. Close the suction valve, stop the machine, and close the discharge valve and main water-supply valve. In shutting down the machine in cold weather *all water should be drained from the system.* This should be done as follows:

130. With main water-supply valve closed and with condenser and compressor water valves wide open, open water-drain cocks at bottom of compressor heads and air-vent cock on top of condenser water head and the water will drain out. These valves and cocks should be left in this position until ready to start up again.

131. To test system for leaks.—When it is first installed and before being charged with ethyl chloride, the system should be tested for leaks as follows:

Close the suction valve, purge valve, charging valve, and pump-over valve and drain valves on the lubricant accumulating and catchall tanks and expansion grid, if these valves are included in the equipment. Open all other valves, including the lubricant-regulating valve. Open the float valve in the trap by screwing down the trap-adjusting valve. Charge the system with lubricant as described in paragraph 142. Break the union in the suction line between the compressor and the suction valve. Start the machine and run until a pressure of 30 pounds is reached. Close the union and test all joints for leaks with soap and water. The compressor stuffing box and all valve stuffing boxes should be tested, as well as pipe joints.

132. To clear the air from the system after testing for leaks, close the discharge valve, break the union in the discharge line between the compressor and the discharge valve, open the suction valve, start the machine, and run until a vacuum of 28 inches or better is obtained. Close the union and open the discharge valve and the machine will be ready for charging.

133. If it is necessary to test for leaks after the system is charged with ethyl chloride, it can be done without drawing off the refrigerant by proceeding as follows:

Close the suction valve, break the union in the suction line between the compressor and suction valve, and run the machine until a pressure

of 30 pounds is obtained. Close the union, shut down the machine, close the suction valve, and test for leaks. If it is desired to test the low-pressure side of the system also, the float valve in the trap should be held open by screwing down on the trap-adjusting valve. Before starting the machine again the air should be purged from the system through the purge valve at the top of the discharge line from the compressor or on top of the condenser, its location varying in different installations. The purge value should be left open until the pressure drops to a point consistent with the temperature of condensing water or until ethyl chloride starts to come out as indicated by its odor.

134. To charge system with ethyl chloride.—A vacuum should be put on the entire system as follows

Close the discharge valve and suction valve. Open all other valves in the discharge and suction lines (not including purge or drain valves) and screw the trap-adjusting valve all the way down. Break the union between the compressor and discharge valve. Start the machine and open the suction valve slowly. Run the machine until the maximum vacuum of which it is capable is obtained (this should be from 28 to 30 inches). Shut down the machine, close the union on the discharge line, close the king valve, and open the discharge valve. Connect the hose from the ethyl-chloride drum to the charging valve and open the valve on the drum first to test the hose for leaks. Start the machine, stand the drum on end, as shown in figure 21, and open the charging valve and the ethyl chloride will be drawn into the system.

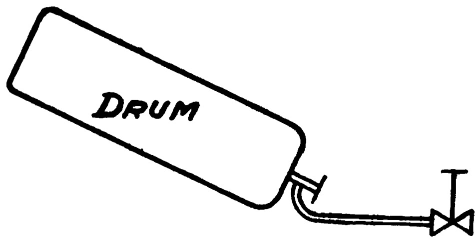


FIG. 21.

135. After the required amount has been drawn in, close the valve on the drum, wait about one minute to clear the hose of gas, and close the charging valve. Open the king valve and screw the trap-adjusting valve back as far as possible, which allows the float valve in the trap to operate. After disconnecting the hose and plugging the charging valve, the system is ready for operation.

136. To add ethyl chloride while machine is in operation.—Close the king valve, connect the hose from the ethyl chloride drum to the charging valve, screw down the trap-adjusting valve, open valve on drum and charging valve, and the ethyl chloride will be drawn in. When a sufficient amount has been added, open the king valve, screw the trap-adjusting valve back as far as possible, close the valve on the drum, wait about one minute, and close the charging valve. Disconnect the hose and plug the charging valve.

137. To drain system of ethyl chloride.—The procedure to be followed in draining the system of ethyl chloride varies slightly with the different installations. With equipments arranged as shown in figures 9 and 10, proceed as follows:

With the machine running, close the trap-shut-off valve, open the float valve in the trap by screwing down on the trap-adjusting valve, and connect the hose from a partly filled or empty ethyl-chloride drum to the charging valve. Open the valve on the drum and test the hose for leaks. Open the charging valve and the ethyl chloride will be pumped into the drum. When the necessary amount has been drawn off, close the charging valve, close the valve on the drum, disconnect the hose, plug the charging valve, and open the trap-shut-off valve.

138. It it is desired to empty the system completely, keep the drum connected to the charging valve until a vacuum of 28 inches or better is obtained. Close the charging valve and the valve on the drum, disconnect the hose, and plug the charging valve. Close the king valve, open the trap-shut-off valve, and shut down the machine. Close the lubricant-regulating valve, open the drain valve on the lubricant-accumulating tank, and draw off the lubricant as described in article 143. When the ethyl chloride starts to flow, close the drain valve and attach the hose from the ethyl-chloride drum to this valve. Open the drain valve, start the machine, and the ethyl chloride will be pumped into the drum. In warm weather it may be necessary to put an air pressure on the system between the compressor and the king valve in order to drain out all of the chemical. To do this, with the drum still connected as above, close the suction valve, break the union between the suction valve and the compressor, and run the machine until all of the ethyl chloride is out of the gauge glass on the lubricant-accumulating tank. *Do not allow the pressure to go beyond 80 pounds per square inch.* Close the charging valve and the valve on drum and disconnect the hose.

139. With the equipments arranged as shown in figure 11, to partially empty the system of ethyl chloride, close the king valve while the machine is running and continue operating until no ethyl chloride shows in the gauge glass on the trap. Close the trap-shut-off valve and open the king valve. Connect the drum hose to the charging valve and proceed as described above.

140. To empty the system completely, run the machine with the drum connected until a vacuum of 28 inches or better is obtained and then disconnect the drum as described above. Close the king valve, open the trap-shut-off valve, and stop the machine. Draw off the lubricant as described in article 143. When the ethyl chloride begins to flow out, close the lubricant pump valve and connect the drum hose to the lubricant drain. Start the machine, open the lubricant pump valve, and the ethyl chloride from the separator will be pumped into the drum.

141. In case it is necessary to put an air pressure on the system, proceed as described above and run machine until all of the ethyl chloride is out of the condenser gauge glass, care being exercised that the pressure does not exceed 30 pounds per square inch. Always stand the drum upright, as shown in figure 22, when emptying the system of ethyl chloride.

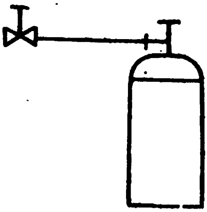


Fig. 22.

142. To charge system with lubricant.—The lubricant, which is chemically pure glycerine, is charged into the system by means of a hand pump.

With apparatus arranged as shown in figure 9, the valve in the lubricant drain line from the separator should be closed and the lubricant pump valve opened, after which the necessary amount of lubricant can be pumped into the system.

With apparatus arranged as shown in figures 10 and 11, it is only necessary to open the lubricant pump valve and operate the hand pump.

The lubricant can be pumped into the system with the machine running or shut down.

The initial charge of lubricant is about 2 pounds.

143. To drain system of lubricant.—With systems arranged as shown in figures 9 and 10, the lubricant is drained off through the drain valve on the lubricant-accumulating tank. The system shown in figure 11 is drained of lubricant by removing the plug in the fitting between the lubricant-pump valve and the lubricant pump. By opening the drain valve on the lubricant-accumulating tank (if installed), or the lubricant-pump valve in the system shown in figure 11, the lubricant can be drained off into a pan or other receptacle. When ethyl chloride begins to flow, the valve should be closed.

144. Lubricant should be replaced in the system when it becomes too thick to flow freely through the sight-feed gauge on the compressor.

145. Lubricant, when once used and drawn from the system, should not be used again.

146. The machine should be shut down when drawing off lubricant to avoid loss of ethyl chloride.

147. To drain expansion grid or brine cooler.—One-half ton installation shown in figures 9 and 10 and larger machines operating with a brine cooler are fitted with a pump-over line for draining the expansion grid or brine cooler of lubricant which may have been carried over with the ethyl chloride. This is accomplished by closing the suction and trap-shut-off valves, opening the pump-over valve, and running the machine about 15 minutes, after which the pump-over valve should be closed and the suction and trap-shut-off valves opened. This pumping-over should be done about once a week when starting the machine.

148. By closing the king valve and screwing down on the trap-adjusting valve when pumping-over and keeping the trap-shut-off valve open the trap can also be pumped out.

149. Expansion grids furnished with equipments arranged as in figure 11 are fitted with a drain valve in the bottom header and the pump-over line is omitted.

150. Equipments shown in figure 10 are also fitted with a hot gas line by means of which the discharge gas from the compressor can be led to the low-pressure side of the system in order to heat and soften the lubricant, in case it became too cold to be pumped out readily.

151. **Abnormally high discharge pressure.**—This may be caused by an insufficient supply of condensing water, by air in the system, or by dirty condenser tubes. The pressure of the ethyl chloride should correspond to the temperature of the outgoing condensing water as given in figure 20.

152. If increasing the supply of circulating water fails to decrease the abnormal discharge pressure of the ethyl chloride, stop the machine and, after waiting about five minutes, open the purge valve. When ethyl chloride begins to flow out, close the purge valve. *Do not attempt to purge the system while the machine is running.*

153. If, after purging and again starting the machine, the pressure continues to build up, it indicates a leak in the suction side of the system, which should be found by proceeding as described in article 131.

154. Do not make repairs on the refrigerant lines without first drawing off the ethyl chloride.

155. In case of continued high pressure, the water side of the condenser tubes should be cleaned. This condition will also cause the difference in temperature of the inlet and outlet condensing water to be very small, indicating reduced transmission of heat through the tubes.

156. **Abnormally high vacuum.**—If accompanied by a low discharge pressure, abnormally high vacuum indicates a loss of ethyl chloride through a leak in the high-pressure side of the system, which can be found as described in article 131.

157. Abnormally high vacuum may also be caused by an obstruction in the liquid line between the trap and cooler or by the float valve in the trap becoming stuck to its seat. Either condition would be indicated by the gauge glass on the trap filling up with liquid ethyl chloride. In such a case screw the trap-adjusting valve down as far as possible, and when the gauge glass empties screw this valve back again.

158. If the gauge glass does not empty when the trap-adjusting valve is screwed down, it indicates an obstruction in the line between the trap and cooler. Clean the line, after first drawing off the ethyl chloride.

159. **Abnormally low vacuum.**—This is caused by loss of the lubricant and is accompanied by a normal discharge pressure. Loss of lubricant is also indicated by liquid ethyl chloride instead of lubricant flowing through the lubricant sight-feed glass and by the disappearance of the lubricant from the gauge glass on the lubricant-accumulating tank or on the condenser if this tank is not installed. The color of the lubricant through the gauge glass is dark, while that of ethyl chloride is light. To remedy, pump in lubricant while the machine is running until it flows freely through the sight-feed gauge.

160. If lubricant shows in the gauge glass on the condenser or lubricant-accumulating tank, but does not flow through the sight-feed gauge, put a pressure on the system by shutting off the condensing water for about five minutes and running the machine with a discharge pressure of 25

to 30 pounds. *Do not allow the pressure to exceed 30 pounds.* If lubricant still will not flow add about ½ pound to the system.

161. Care of valves.—All valves should be inspected about once a month and the stuffing boxes tested for leaks. Glycerine cup valves should be cleaned and refilled about once every two months.

162. Functions of valves (refer to figs. 9, 10, and 11).—The location and functions of the various valves are as follows:

(*a*) *Discharge valve.*—In discharge line from compressor—to be wide open when machine is running and closed when machine is shut down.

(*b*) *Suction valve.*—In suction line from cooler—to be wide open when machine is running and closed when machine is shut down.

(*c*) *King valve.*—In liquid refrigerant line between lubricant-accumulating tank and trap in figures 9 and 10 and between separator and trap in figure 11—to be wide open when machine is running and closed only at such times as noted in the foregoing instructions.

(*d*) *Charging valve.*—On side of trap in figures 9 and 10 and in liquid refrigerant line between king valve and trap in figure 11—to be open when charging system or drawing off ethyl chloride and to be closed and plugged at all other times.

(*e*) *Trap-adjusting valve.*—On top of trap at outlet end—to be screwed back as far as possible at all times except as noted in the foregoing instructions.

(*f*) *Trap-shut-off valve.*—In liquid line between trap and catchall tank in figure 9 and between trap and cooler in figures 10 and 11—to be wide open when machine is running and closed only as noted in the foregoing instructions.

(*g*) *Purge valve.*—At top of compressor discharge line in figure 9 and on top of condenser in figures 10 and 11—to be opened only when purging air from the system and closed and plugged at all other times.

(*h*) *Chemical vent valve.*—In vent line between trap and condenser in figures 9 and 10 and between trap and suction strainer in figure 11—to be wide open in installations shown in figures 9 and 10 and open one quarter turn with installations shown in figure 11 while operating.

(*i*) *Lubricant-regulating valve.*—In lubricant line between lubricant-accumulating tank and compressor in figures 9 and 10 and between separator and compressor in figure 11—to be open when machine is running and closed when shut down.

(*j*) *Lubricant pump valve.*—Between lubricant pump and lubricant line—to be open when pumping lubricant into system or draining lubricant and ethyl chloride out of system and closed at all other times.

(*k*) *Pump-over valve.*—In pump-over line between cooler and suction line—to be open only as noted in the foregoing instructions and closed at all other times.

(*l*) *Hot gas valve.*—In hot gas line between compressor discharge and suction pipes—to be open only as noted in the foregoing instructions and closed at all other times.

163. Precautions in operating.—The following precautions should be observed in operating this type of machine:

(*a*) Maintain a steady flow of lubricant at all times.

(*b*) Maintain a steady flow of water to condenser and compressor at all times.

(*c*) Carry about 1½ inches of liquid in the trap gauge glass when operating.

(*d*) Drain the water from the system when shutting down in cold weather.

(*e*) Use only chemically pure glycerine as a lubricant in the compressor.

(*f*) Clean the strainers about twice a year.

(*g*) Do not attempt to start the machine with the discharge valve closed.

164. To repair compressor.—When the compressor becomes worn so as to develop a knock when running or it will not pull 28 inches vacuum with the suction valve and pump-over valve closed or the suction valve and vent valve closed, if no pump-over valve is installed, it should be removed from its base and overhauled.

To remove the compressor, first close the suction and discharge valves, the lubricant-regulating valve, and the pump-over valve if fitted. After breaking the unions in the suction and discharge lines and disconnecting the lubricant line, the compressor may be uncoupled from the motor or engine and removed from its base.

When overhauling the compressor after it has been removed from the base, stand it on the back head and remove the stuffing-box head. A convenient method of supporting the compressor while working on it is shown in figure 23.

The clearance between the walls of the cylinder and the packing strips should be between 0.002 inch and 0.004 inch at all points so that the rotor will turn freely. This clearance should be measured at all points, such as A, B, C, D, etc., in figure 23.

In case the packing strips are worn and the clearance exceeds 0.004 inch, the hexagonal spacing pins can be stretched by hammering them on all the flat sides until the proper clearance is obtained.

If the wear on the packing strip is sufficient to warrant it, replace the old strips with new ones.

Replace the blades and spacing pins in the same places from which they were removed, as indicated by the numbers on the ends. The blades should be replaced with the oil grooves on the side away from the pressure as shown in figure 23.

When the head is replaced, see that the jacking screws are backed out and the dowel pins are in their proper places.

Draw the head up tight, as any excess and clearance will impair the efficiency of the machine. The rotor should not bind when turned over.

If, after the spacing pins are stretched and the clearance between the packing strips and the cylinder is reduced to not more than 0.004 inch the compressor will not pull a 28-inch vacuum, it is probably due to wear on the rotor, and a new rotor should be installed.

When renewing the packing in the stuffing box, care must be taken that the lantern gland is replaced under the connection from the lubricant line.

Keep all dirt from the compressor when replacing parts after overhauling. It is not advisable to remove both heads at the same time, as the assembly of the machine is thereby made considerably more difficult.

The compressor cylinder should never be rebored under any circumstances, as the cylinder is bored elliptically, the work being done in a special fixture.

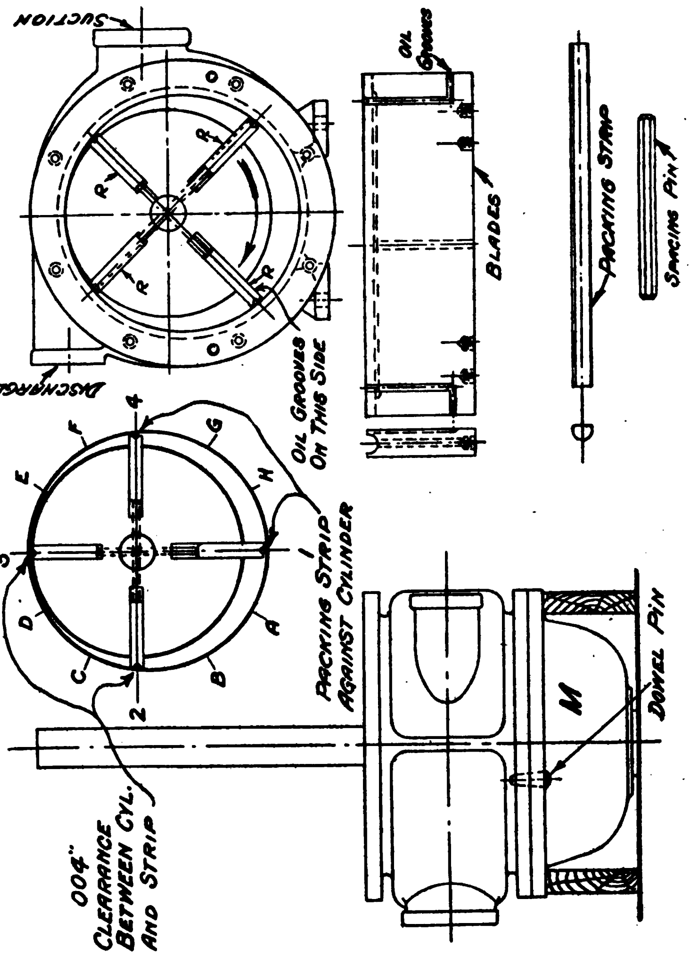

SUCTION
DISCHARGE
R
OIL GROOVES ON THIS SIDE
OIL GROOVES
BLADES
PACKING STRIP
SPACING PIN
A
B
C
D
E
F
G
H
1
2
3
4
PACKING STRIP AGAINST CYLINDER
M
DOWEL PIN
.004" CLEARANCE BETWEEN CYL. AND STRIP

FIG. 23.

165. Cleaning the brine cooler.—In case it is necessary to clean the brine-cooler tubes, the refrigerant and brine should be drawn from the system, the brine-cooler head taken off, and the tubes cleaned inside and outside. In replacing the head, care should be taken in fitting the rubber gasket in the grooves, and the head should be put back very securely to prevent leaks.

After replacing the head, the system should be tested for leaks before it is recharged. An indication of dirty brine tubes is inability to cool the brine to a low temperature with the machine operating with proper ethyl-chloride pressures, accompanied by a very small difference between the temperatures of the incoming and outgoing brine.

166. Brine in congealing tank.—The expansion grid furnished with ½-ton equipments arranged as shown in figures 9 and 10 is fitted in a congealing tank in the refrigerator box, and this congealing tank should be kept filled with brine of sufficient density to prevent its freezing. The density of the brine should be from 1.125 to 1.18, the corresponding freezing points being given in the table of calcium-chloride solutions. The specific gravity should be taken about once a month and strong calcium-chloride solution added if the mixture is weak.

167. For suggestions applicable to all types of machines see articles 217 to 222, and for instructions for operation of brine and ice making systems see articles 223 to 227.

Section 4.—AMMONIA MACHINES.

OPERATION.

168. Principle.—The principle of this machine is the same as in the CO_2 machine. The refrigerant is ammonia anhydride, a colorless, irrespirable gas, with an easily recognizable odor. It is slightly combustible when mixed with a sufficient proportion of air, and when mixed with twice its volume of air is capable of being exploded with great violence. It attacks copper and its alloys, so that none of these can be used in the construction of parts of the machine that come in contact with ammonia. Ammonia liquifies at a pressure of 128 pounds per square inch at a temperature of 60° F., and the liquid boils at a temperature of 4° F. at atmospheric pressure.

In this machine the gas is drawn from the system into the compressor cylinder and compressed to about 180 pounds per square inch. The work of compressing heats the gas, which is then discharged through the oil interceptor to the condenser, where the circulating water cools the gas and condenses it to a liquid. From the condenser the liquid passes to the liquid receiver, then through the main liquid valve to the regulating (expansion) valve, and then to the cooling coils in direct-expansion systems and to the evaporator in brine systems. From the cooling coils or evaporator the gas returns to the compressor at a pressure between 15 and 30 pounds, completing the cycle of operations.

169. Cleaning the system.—Before starting a new plant great care should be exercised to thoroughly clean all parts of the system, as the ammonia will loosen all scale and dirt remaining in the system and this foreign matter is sure to cause much trouble.

170. Testing the system.—Before charging a new plant with ammonia, or after overhauling an old one, test it to 300 pounds per square inch with

air. To do this the stop valve is closed on the suction line, and the valves provided on the suction side of the compressor to connect it with the atmosphere are opened. In case there are no valves provided, a flange joint between the stop valve and the compressor may be broken and held apart with wedges. All other valves of the system, excepting those which communicate with the atmosphere, as drains of oil tank, etc., should be open so that the pressure will be removed and equalized over the entire system. The compressor heads are removed and a very small quantity of cylinder oil rubbed on the inside of the cylinder to prevent heating, but if too much oil is used it may be the cause of an explosion. The heads are then replaced and the bolts set up evenly and tight. By running the machine slowly, air is drawn in and compressed until the entire system of pipes, etc., is under pressure of 300 pounds per square inch. Care should be taken to see that stop valve on the discharge pipe is open, for otherwise excessive pressure will be had in the compressor at starting and a dangerous accident, such as the blowing out of a cylinder head, may be the result of the oversight. In pumping up the air pressure, the machine should be immediately stopped if the discharge pipe or compressor become excessively hot.

Having obtained the desired test pressure in the system, the machine is shut down and the stop valve on the discharge line is closed, soap lather is spread over all the pipes, flanges, valves, and connections, and a very close and systematic inspection of the system from the compressor to the last joint of the pipe line is carefully made.

171. Leaks.—Leaks at joints should be remedied by tightening the bolts or by new gaskets. All leaks are detected by the appearance of bubbles in the soap lather; those on the pipes may be round holes, or may be in the direction of the pipe length. It is good practice to renew any section of pipe that shows any signs of leaks, but if it is not possible to renew, the leaks may be repaired by using solder and a short clamp. A small round hole is repaired by filling it with solder. Some of the holes are very small and can be detected only with the aid of a magnifying glass. Every care should be taken to detect and stop them, as otherwise more or less loss of ammonia will be incurred when the system is charged.

After all the repair work is done the plant should be allowed to stand for several hours, at the end of which time the pressure will be same as at first, provided everything is tight. In any case the gauge should not fall more than 20 pounds.

Before letting the air out it is best to blow through all valves and pipe to make sure that they are clear and to thoroughly free the system from all dirt and moisture. The air then is let out by opening the valves at the lowest point, or points, on the system, such as at the bottom of the oil-separator reservoir, and expansion coils.

172. Charging.—It is next necessary to pump the air out of the system and to get as near a perfect vacuum as possible. This is done by closing the compressor-discharge stop valve and all the valves that communicate with the atmosphere. Communication with the atmosphere is then made between the stop valve just closed and the compressor. There is usually a valve provided for this purpose. Next open all suction and discharge valves in the system except the one just mentioned, and start the compressor slowly. By running the compressor the air in the system is pumped out until the gauge shows 30 inches. If a vacuum of

30 inches can not be obtained, at least a 28-inch vacuum should be obtained before stopping the compressor. This being done, close the discharge valve to the atmosphere and the machine is ready for charging.

Liquid anhydrous ammonia is shipped in cylindrical steel drums. They vary in size, ranging from 50 pounds to 110 pounds. The shell is about one-fourth inch thick. A valve is provided at the end for connecting the charging pipe, and a false head over the end of the drum protects the valve during shipment. These drums should be handled with great care and should never be jarred nor exposed to the heat of the sun. Anhydrous ammonia acts in some cases as an explosive and expands when the flask is moved suddenly. When the flasks are stored they should be kept in a cool place. A connection for charging is provided on or near the liquid-ammonia receiver near the expansion valves, and the flask should be connected to this by a three-eighths-inch pipe; the other end should be elevated about 12 inches. The valves on the flask should be opened very carefully at first to see that the connections are tight, and then closed.

If the connections are found to be tight, turn on the circulating water; have a pail of water standing by in case of leaks. If a double-acting compressor, pump oil in the stuffing box of the compressor; if a single-acting compressor, see that the gauge glass on the compressor-crank case is half full of ice-machine oil; open the stop valves on the compressor discharge and suction; close the main liquid valve which is between the charging valve and the liquid receiver; start the machine running slowly; open the charging valve and gradually open the valve on the flask. It is best to charge the system by degrees. At the first charging about 70 per cent of the whole amount to be used is put into the system and thoroughly circulated, after which the air will be found in the top of the condenser, or at the high point of the system, where it can be allowed to escape to atmosphere through the purging valve. Rather than allow the air to escape to the atmosphere it is better to connect one end of a flexible rubber hose to the purge cock, the other end being led into a bucket of water. When the purge cock is open the air will come away and will be seen in bubbles in the water, and there will be no smell as long as air is coming. When all the air has been driven out and ammonia commences to pass, the bubles will disappear, the smell of ammonia will be noticed, and the purge cock should be immediately closed. The remaining ammonia is charged in one or two installments, the air being allowed to escape in the same manner before each successive charging. To get all of the ammonia out of the drum, it is advisable to heat the drum with hot water, or a blow torch if carefully used. In this way the frost formed on the inside of the drum is removed and the ammonia is allowed to run out. In disconnecting the drum, close the charging valve first and then close the valve on the flask. It is usual to charge the system with one-third pound of ammonia for each running foot of 2-inch pipe or its equivalent in expansion coils. Certain installations of the Brunswick 1-ton machines required 50 pounds of ammonia to fill the system, and, as a rule, when the machine is installed the makers will have supplied this information. In charging, it is better to charge too little than too much, because the additional amount may be added at any time.

173. Detecting leaks after charging.—Ammonia leaks may be easily detected by the use of soapy water or by the use of red litmus paper, as follows:

(*a*) Leaks in the condenser: Immerse the litmus paper in the circulating-water discharge, and the presence of ammonia, no matter how little, will be indicated by the paper turning blue.

(*b*) Leaks in submerged coil of (evaporator) ice-making or brine box: Immerse the litmus paper in the brine, and if ammonia is present the litmus paper will turn blue.

(*c*) Leaks in the expansion coil or system: Dampen the litmus paper and run it along the coil or pipe and upon coming in contact with the leak the paper will turn blue.

A more delicate test of the brine and the circulating-discharge water may be made by the use of Nessler's reagent. This "consists of 17 grams of mercuric chloride dissolved in about 300 cubic centimeters of distilled water, to which is added 35 grams of potassium iodide dissolved in 100 cubic centimeters of distilled water, and constantly stirred until a slight permanent red precipitate is produced. To the solution thus formed is added 120 grams of potassium hydrate dissolved in about 200 cubic centimeters of distilled water, allowed to cool before mixing; the amount is then made up to 1 liter, and mercuric chloride added until a permanent precipitate again forms. After standing for a sufficient time, the clear solution can be placed in glass-stoppered blue bottles and kept in a dark place. If a few drops of this reagent be added to a sample of the suspected brine or water in a test tube or other small vessel, and the slightest trace of ammonia is present, a yellow coloration of the liquid will take place; a large quantity of ammonia will produce a dark brown." A very convenient and sure method of testing for leaks in exposed piping and joints is by the use of sulphur sticks. Melt in a metal receptacle ordinary sulphur or brimstone, being careful not to burn it, then dip and redip thin strips of wood or cardboard in the sulphur until a coating about one-sixteenth inch thick is formed on them. Light one end of a sulphur stick made as above and pass it along the part of the system to be tested. Any leak of ammonia will be shown by the appearance of dense white smoke about the burning sulphur.

174. Starting.—As a rule, every particular type of machine operating on this principle has certain distinctive features, but the following instructions will generally be applicable to any type of machine. See figure 24. To start the machine see that the gauge glass on the compressor-crank case is half full of oil; see ring oiler on outboard bearing is supplied with oil; open circulating-water supply valve No. 1 to condenser; see circulating-water supply to compressor jacket open. See that suction valve No. 3 is closed, open wide discharge by-pass valve A, jack machine until at compression point; start the macnine, then be sure to open discharge valve No. 2, next close by-pass valve A, and open suction valve No. 3 one-quarter turn. Run machine slowly until suction gauge shows 10 pounds pressure, then gradually open wide suction valve No. 3. Open liquid valve No. 4 and regulate the regulating (expansion) valves. After the machine is started as above, note carefully the temperature of the compressor discharge pipe. This pipe should be *slightly warm;* if it becomes hot it is a sign that the liquid ammonia is not passing through the regulating valve as rapidly as it should. If at the same time the frost either wholly or partially disappears from the suction valve it is a

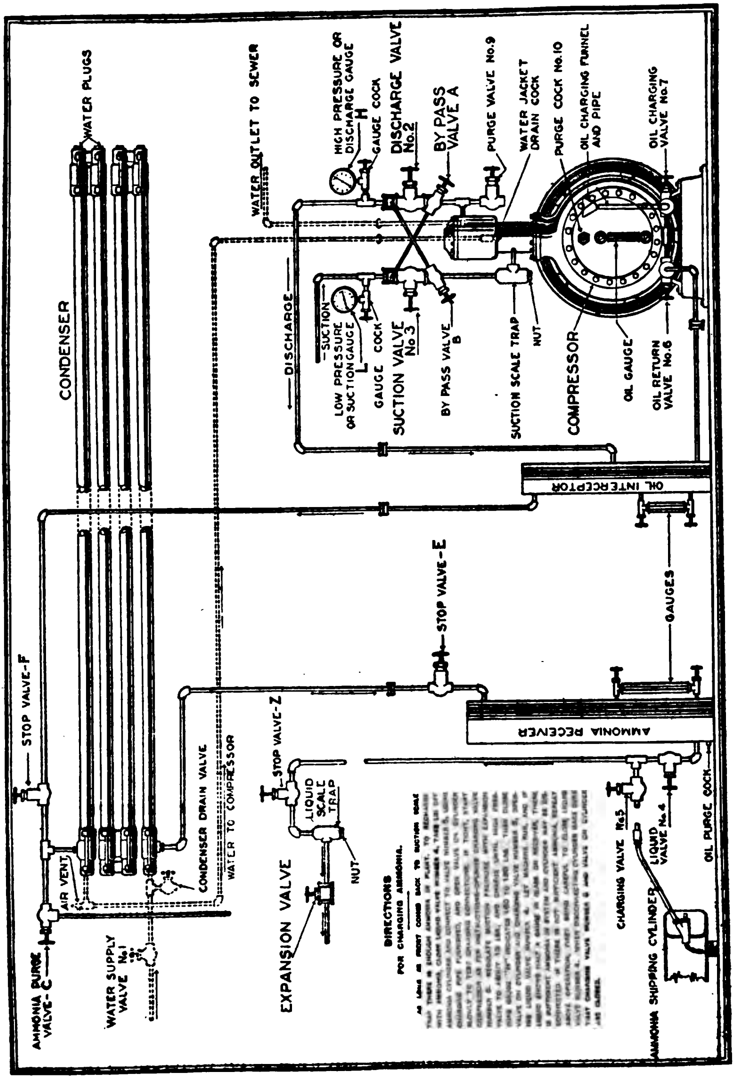

CONDENSER
WATER PLUGS
WATER OUTLET TO SEWER
HIGH PRESSURE OR DISCHARGE GAUGE H
GAUGE COCK
DISCHARGE VALVE No. 2
BY PASS VALVE A
PURGE VALVE No. 9
WATER JACKET DRAIN COCK
PURGE COCK No. 10
OIL CHARGING FUNNEL AND PIPE
OIL CHARGING VALVE No. 7
DISCHARGE
SUCTION
LOW PRESSURE OR SUCTION GAUGE L
GAUGE COCK
SUCTION VALVE No 3
BY PASS VALVE B
SUCTION SCALE TRAP
NUT
COMPRESSOR
OIL GAUGE
OIL RETURN VALVE No. 6
OIL INTERCEPTOR
GAUGES
STOP VALVE-E
STOP VALVE-F
AMMONIA RECEIVER
STOP VALVE-Z
LIQUID SCALE TRAP
NUT
EXPANSION VALVE
CONDENSER DRAIN VALVE
WATER TO COMPRESSOR
AIR VENT
WATER SUPPLY VALVE No. 1
AMMONIA PURGE VALVE-C
DIRECTIONS FOR CHARGING AMMONIA.
CHARGING VALVE No. 5
LIQUID VALVE No. 4
OIL PURGE COCK
AMMONIA SHIPPING CYLINDER

FIG. 24.

sign that the regulating valve should be opened a little more. If the discharge pipe becomes cooler than it should be the regulating valve should be closed a little. In adjusting the regulating valve it should be remembered that a very small change in the opening of this valve has a comparatively large effect on the amount of liquid passing through it and that the effect of a slight adjustment of this valve is not apparent for several minutes. Do not change the regulating valves unnesessarily, as too much adjusting of these valves causes the packing to wear out and leak.

175. Pressure.—The pressure gauges are marked in pressures and the corresponding temperature on two concentric circles. The pressure that should be carried on the condenser depends upon the temperature of the circulating water available, because the ammonia pressure depends upon its temperature. The condenser pressure should be carried at the pressure corresponding to a temperature about 10 degrees above the temperature of the discharge-circulating water. The pressure corresponding to a given temperature can be found from the following table:

Properties of saturated ammonia gas.

Temperature, Fahrenheit.	Pressure, pounds per square inch.	Latent heat of evaporation.	Weight of vapor, pounds per cubic foot.
100	200.42	492.01	.7153
90	167.92	498.55	.6120
80	139.40	505.05	.5205
70	114.49	511.52	.4401
60	92.89	517.93	.3697
50	74.26	524.30	.3084
40	58.29	530.63	.2554
30	44.72	536.91	.2099
20	33.25	543.15	.1711
10	23.64	549.35	.1383
0	15.67	555.50	.1107
—10	9.10	561.61	.0878
—20	3.75	567.67	.0690
—30	—0.57	573.69	.0535
—40	—4.01	597.67	.0410

For example, if the temperature of the discharge-circulating sea water is 80° F., the condenser pressure should be that which corresponds to 90° F., or about 168 pounds.

The evaporator or suction pressure should be that corresponding to a temperature 10° F. below that of the brine in the brine tank, where the expansion coils are immersed in brine, and to a temperature 20° F. below that of the air if the expansion coils are cooling air direct. For example, if the temperature of the brine is 10° F., the suction pressure should be that corresponding to 0° F., or 15.67 pounds per square inch; or if the temperature of the air in rooms cooled by direct expansion coils is 20° F., the suction or evaporator pressure should be about 15 pounds per square inch.

If the pressure given above, making allowances for differences in temperatures of circulating water and brine, are maintained and the hands of the pressure gauges pulsate at every stroke of the piston, it is probable that the machine is working properly.

176. To charge compressor case with oil.—Since in time the oil will lose its lubricating value, it should be replaced by new oil once every six months. This may be done as follows: First, close liquid valve No. 4 and operate compressor, pumping down until low-pressure or suction gauge L indicates 5-inch vacuum. Then close suction valve No. 3 on compressor and stop machine, immediately closing discharge valve No. 2 on compressor. By-pass valve A should now be opened to allow pressure in machine to equalize with low-pressure side and immediately closed again. Then slowly open purge valve No. 9 and purge cock No. 10 on the front of the compressor case. Oil-charging valve No. 7 may now be opened and the old oil drawn out of the case. After all the old oil has been drawn out, connect a piece of one-half-inch pipe with elbow and nipple pointing upward to oil-charging valve No. 7, and attach a funnel, pouring in the new oil until gauge glass is half full. Then close oil-charging valve No. 7, purge cock No. 10, and start machine, pumping air out through purge valve No. 9. After the air is all pumped out, close valve No. 9, open discharge valve No. 2 at once, and operate machine as usual. When fully charged, the oil level gauge on compressor case should show about one-half full.

177. Scale traps.—The scale traps should be examined and cleaned out at least once each year, and at least twice in the first year after the machine has been installed. This may be readily done when the system is pumped down—for instance, when renewing the oil, it being necessary only to unscrew the nut on the end of the scale trap in order to remove the screen. Before cleaning scale traps on ammonia liquid line, be sure to close liquid valve No. 4, and pump ammonia out of liquid line between valve No. 4 and scale trap.

178. Circulating water.—On board ship where the circulating water can be supplied at no cost except the small amount of power used it is best to use the full capacity of the system, because the lower the temperature of the discharge-circulating water the lower the condenser pressure that can be carried and the less the work required of the compressor.

179. Faulty operation.—If the machine is not working properly it may be due to one of the following causes:

1. Shortage of gas in the system.
2. Air in the system.
3. Oil in the system.
4. Leaking valves.
5. Defective packing.

180. Insufficient gas in the system.—If the regulating valve can not be adjusted so as to keep the compressor-suction pipe frosted and the discharge pipe warm the trouble is probably due to insufficient gas in the system. The fact that the system is short of ammonia may be known for certain by placing the ear near the regulating valve; if gas is passing through the valve a distinct whistling sound will be heard, but if there is no shortage of ammonia only liquid will be passing through the valve and the sound will be a hissing one easily recognized by the operator. If there is insufficient ammonia add more to the system until the gauge glass on the liquid receiver shows sufficient liquid or until the frost on the compressor suction pipe appears. Be careful not to overcharge the system.

181. Air in the system.—If there is air in the system, it displaces a certain amount of gas that should be in use, and the indications of the

presence of air are much the same as those of a shortage of ammonia, except that unusually high condenser pressure will be noted and the passage of the liquid through the regulating valve will be interrupted by air bubbles, which will give an intermittent whistling sound. The remedy is to remove the air, as previously described, and add more liquid ammonia if needed.

182. Oil in the system.—The presence of any considerable amount of oil or water in the system will cause a reduction in efficiency and will be indicated by shocks within the compressor cylinder. The oil should be removed through the drain valve on the oil interceptor.

183. To return oil from interceptor to compressor.—A certain amount of oil will pass up out of the case and through the cylinder to the oil separator, and it is necessary to return this oil to the case when the oil level is within about one-half inch of the bottom of the gauge glass on compressor case. The oil should be blown back from oil separator or interceptor as follows: First, with machine operating as usual, make sure that the valves or cocks on oil level gauges on the front of compressor case and on oil interceptor are open; then slightly open oil-return valve No. 6 on the bottom of compressor case. The oil will then be forced through the oil-return pipe from separator to compressor case by the high pressure in the separator. During this operation the oil level in separator gauge must be watched carefully, and as soon as the oil disappears from the glass valve No. 6 must be closed tight. If valve No. 6 is not closed tight immediately after the oil disappears from separator gauge, ammonia will follow, passing through the oil-return pipe into compressor case. A certain amount of ammonia liquid will sometimes collect on top of the oil in interceptor, and the operator is cautioned not to mistake this for oil and return it to compressor case. If a quantity of ammonia gets into the compressor case, excessive pressure will result, making the machine very hard to start; or if the machine is running it will labor, consuming extra power and sometimes even stopping the motor or throwing the belt off. Finally, ammonia mixed with oil may cause the oil to boil over past the lower piston rings into the cylinder, and so on through to the separator again, making it necessary soon to blow the oil back once more. Never return the oil from separator to compressor except when machine is running. If any ammonia goes through with the oil, it will evaporate and pass up into the cylinder more easily when machine is in operation.

184. Leaking compressor valves.—If either valves or piston are suspected of leaking, the fact may be determined with a fair degree of certainty by closing the regulating valve and continuing the machine in operation. The evaporator (suction) pressure should be pumped down to about 20 per cent of what it was in a certain number of revolutions, which should be stated by the manufacturer of the particular machine or determined on board ship when the machine is known to be in good condition. If the valves are leaking it should be possible to detect this by listening carefully with the ear near the compressor cylinder. Irregular and faulty action of the valve should be indicated by the irregular pulsation of the pressure gauges. If the valves are leaking badly it will be impossible to pump down the suction pressure in order to remove the valves, so that the gas should be expelled from the cylinder as follows: Close the regulating valves tight, then close the compressor suction stop valve, stop the machine, turn the machine to top center, close the discharge stop valve, then turn the machine one complete revolution; open the dis-

charge stop valve to let the pressure blow into the condenser. Repeat this operation several times, then open the cylinder, having water and a large wet sponge at hand to absorb the ammonia remaining in the cylinder.

185. **Defective packing.**—If the compressor valves are in good condition, sufficient gas in the system, no other faults located, but the machine shows decreased capacity, the piston packing is probably worn and should be examined.

186. **Shutting down.**—To stop the machine, close the expansion valve or, better, the liquid valve between the expansion valve and the liquid receiver; pump the low-pressure side of the system down to a pressure of 2 pounds. Do not pump down to a vacuum. Close the suction stop valve, stop the machine, close the discharge stop valve, and shut off the circulating water.

187. **Adjusting lift of valves.**—Special attention should be given to the lift of the compressor valves, for if the lift is too high the valves will not close promptly, and the machine will be inefficient, especially if the machine is run at high speed.

188. **Removing oil from system.**—The system should be completely freed from oil when opportunity offers, as it clogs up the pipes, reduces the efficiency of the machine and the conductivity of the piping. To remove the oil, stop brine pump, slow down the circulating pump, let the hot ammonia circulate through the system, open expansion valve equalizing the pressure on the high and low sides. The oil is carried through the system back to the oil interruptor or trap, and this trap should be blown down every 15 minutes until the system is free of oil. After the system is free of oil the machine may be started up or shut down in the usual way, increasing the supply of circulating water and closing the regular valve.

189. **Care and packing of valves.**—All valve stems should be kept well oiled at all times to prevent rust and to insure free operation. To prevent loss of ammonia, with the attendant disagreeable odor, and to insure also against air getting into the system when operating under a vacuum, it is necessary to keep all valve stuffing boxes tight. If the valve stuffing boxes are properly packed with a good grade of packing they may be kept absolutely ammonia tight without sufficient pressure being applied to make the stem turn stiffly. The glands should be kept just tight enough to prevent any leakage of ammonia. If kept too tight, the valve stem will bind. In time the valve packing will dry out and become hard, causing the stem to bind and turn stiffly, and sometimes causing valve bonnet to turn with stem. When this condition exists, although there may still be some room for adjustment of gland nut, and there may also be no leakage, the packing should be replaced, first completely removing the old packing. When the gland is drawn up as far as possible and yet the stem works freely, the addition of one or two rings of packing may be sufficient without removing the old packing. Any good grade of ammonia packing may be used. All ammonia valves on closed lines—that is, all ammonia valves, except gauge cocks, expansion valves, and the charging and purge valves, which have one end open to the atmosphere—should be repacked when wide open, since they are double-seated valves, and the ammonia can not leak out through the stuffing box when they are opened full against the upper seat. Gauge cocks, purge valves, and charging valves are subjected to pressure only on one side, and therefore

must be packed when closed tight. When repacking ammonia or oil-level gauge cocks, the nuts should be loosened slightly and the ammonia allowed to escape before removing nut entirely. It is necessary to remove the pressure from both sides of the expansion valve in order to repack it. This may be done by closing liquid valve No. 4 and pumping the system down to a vacuum, after which suction valve No. 3 may be closed and expansion valve taken apart; or in case there is a valve between the low-pressure side and the expansion valve this valve should be closed, preventing air (which would have to be pumped out) from getting into the coils. Where there is more than one expansion valve, or if the expansion valve is located at some distance from ammonia receiver, stop valve Z may be closed in place of liquid valve No. 4 when pumping out low-pressure side between expansion valve and compressor, or if for any reason it is necessary to shut off any one section of the expansion system.

190. What to do in case of a leak in high pressure.—See figure. If a leak occurs in any part of the high-pressure side, except between liquid valve No. 4 and expansion valves, stop machine, closing suction valve No. 3 and discharge valve No. 2 as usual; and unless the leak is on the ammonia receiver, close the nearest valves on each side of the leak and also close liquid valve No. 4 at once. If the leak is in or near the oil separator, between stop valve F and discharge valve No. 2, close stop valve F. If the leak is in or near the condenser, between stop valves E and F, close stop valves E and F. If the leak is on the ammonia receiver, liquid valve No. 4 and expansion valve or valves should be opened wide at once, which will allow a great quantity of the ammonia to pass from the receiver into the low-pressure side of the system, relieving the pressure to some extent. If the leak is not serious—for instance, if it is in a joint of the condenser or some flange, so that it can be stopped by tightening the bolts—it may be repaired without removing the ammonia from the high-pressure side. If, however, the leak is so serious that it is necessary to disconnect the piping or apparatus, the ammonia should be pumped out of the high-pressure side and into the low-pressure side before attempting to make any repairs. Before starting the machine to pump the ammonia into the low-pressure side, make sure that the proper valves on each side of the affected part, which have been closed, are opened again as follows: If the leak is on or near the oil separator or in by-pass valve B, the stop valve F should be left closed and the machine started at once as described later. If the leak is on or near the condenser, open stop valve F, leaving stop valve E closed. If the leak is on or near the ammonia receiver, first open liquid valve No. 4 and expansion valves to allow as much of the ammonia as possible to pass into the low-pressure side, as described above. Then close liquid valve No. 4 again.

191. To pump ammonia from high-pressure side into low-pressure side.—First, make sure that the valves are set as described on preceding page. Then open wide by-pass valve A and start compressor. Next, open by-pass valve B slightly and allow machine to operate until high-pressure gauge H shows 25 pounds pressure. Then gradually open by-pass valve B wide and run machine until high-pressure gauge H registers 15 to 20 inches vacuum and all ammonia has been pumped out of the affected parts. Be sure that gauge cocks on oil separator or ammonia receiver are wide open, since even after high-pressure gauge H shows a vacuum there may still be a quantity of ammonia left in the system;

so it is necessary to keep the machine running until all ammonia disappears from the gauge glass.

By-pass valve B should now be closed and machine stopped, immediately closing by-pass valve A also. If high-pressure gauge H rises above 0 inside of 10 to 15 minutes, indicating that there is still some ammonia present, the machine should be started again and the system pumped out once more as described above. After repeating this process until all ammonia is pumped out and high-pressure gauge H still registers a vacuum when machine has been stopped 10 to 15 minutes, purge valve No. 9 and discharge valve No. 2 should be opened to allow any ammonia which is in the machine to escape, after which the necessary repairs may be made. After the leak has been repaired, close discharge valve No. 2 and proceed as follows to pump air out of the system: Make sure that purge valve No. 9 on compressor discharge pipe is open and also open wide by-pass valve B, keeping by-pass valve A closed. Start compressor and operate until high-pressure gauge H shows 15 inches to 20 inches vacuum. Then close by-pass valve B and purge valve No. 9, and immediately stop compressor. Before starting machine again and returning ammonia to repaired portion, it is advisable to test the repaired parts by allowing a small quantity of ammonia to return through liquid valve No. 4 (or stop valve E or F, as the case may be), which should be slightly opened and closed again quickly as soon as high-pressure gauge H shows 10 pounds. If all parts are tight, liquid valve No. 4 (or stop valve E or F) may then be opened slowly until wide open, and the machine started in the usual manner.

192. What to do in case of a leak in the compressor.—If a leak occurs in the compressor or in the piping between compressor and by-pass valve A, or if for any reason it is necessary to take the compressor apart, proceed as follows: Close liquid valve No. 4 and then suction valve No. 3, allowing compressor to run for two or three minutes to reduce pressure in compressor case. Then shut off power and close discharge valve No. 2 tight at once. By-pass valve A should now be opened to allow pressure in machine to equalize with low-pressure side, and immediately closed again. Purge valve No. 9 should then be opened gradually, after which the compressor may be taken apart or the leak repaired. After necessary repairs have been made, start compressor, pumping air out through purge valve No. 9. When all air is expelled, close purge valve No. 9 and immediately open discharge valve No. 2, and then gradually open suction valve No. 3, operating the machine as usual.

193. What to do in case of a leak in low-pressure side.—If a leak occurs in any part of the low-pressure side or expansion coils or between liquid valve No. 4 and suction valve No. 3, or in by-pass valve A on the compressor, liquid valve No. 4 should be closed at once and machine operated until low-pressure or suction gauge L registers 15 inches to 20 inches vacuum. The machine should then be shut down and discharge valve No. 2 closed tight. If low pressure rises above 0 inside of 10 to 15 minutes, indicating that there is still ammonia present in the coils, discharge valve No. 2 should be opened and the machine started again, the operation of pumping down being repeated. After repeating this process until all ammonia is pumped out, and low-pressure gauge continues to register a vacuum, open by-pass valve A and then purge valve No. 9, after which the necessary repairs may be made. After repairs

have been made, all air must be expelled from the system as follows, First, close by-pass valve A, making sure that purge valve No. 9 is open: and start compressor; then open suction valve No. 3, pumping out air through purge valve No. 9. When all air is expelled, close suction valve No. 3, then purge valve No. 9, and stop machine. If low-pressure gauge L continues to register a vacuum for 5 or 10 minutes, the piping may be considered tight; but as an extra precaution it is well to open liquid valve No. 4 slightly and close it again quickly as soon as low-pressure gauge L shows 5 pounds pressure. If all parts are tight, start machine in the usual manner, as previously described.

194. Ammonia in oil interceptor.—If the oil interceptor is in a cool place, or if machine is operated at too high a suction pressure and "frosts back" heavily, ammonia will collect in the oil interceptor, which condition, however, is not in any way harmful unless the ammonia rises near the level of the gas inlet from the compressor. To relieve this condition, close expansion valves sufficiently to keep discharge pipe hot.

195. Excessive pressure in compressor case.—Excessive pressure in compressor case may be caused, as already described, either by operating at too high a suction pressure and "frosting back" heavily, or by passing ammonia into the case when returning oil from interceptor. If this occurs when machine is running, making compressor labor, close liquid valve No. 4 and pump down low-pressure side to from 10 inches to 15 inches vacuum, which will cause the ammonia in the compressor to evaporate.

If the compressor, being shut down, is difficult to start, open suction valve No. 3, making sure that discharge valve No. 2 and by-pass valve A are closed, and allow the machine to stand for 15 to 20 minutes, permitting the pressure in the case to equalize with the suction pressure. Before starting machine again, be sure to close suction valve No. 3 and then open by-pass valve A and proceed as usual. If the suction pressure is so high that this procedure fails to relieve the pressure in the case, slightly open purge cock No. 10 and relieve pressure into atmosphere or water. All valves on compressor should be closed when this is being done.

196. To purge oil from ammonia receiver.—If oil is returned at proper intervals from oil interceptor to compressor case, very little will collect in the ammonia receiver. However, if for any reason oil should collect in the receiver, it may be drawn off through the small purge cock which will be found on the bottom of the vertical type of receiver, or through the purge valve on bottom of the horizontal type. This cock, or valve, as it may be, should be opened very slightly to prevent loss of ammonia or too sudden discharge of the oil. The oil will pass out of the receiver in a frothy or foamy condition, due to being impregnated with ammonia. Oil, being heavier than ammonia, will always lay in the bottom of the receiver, and being darker in color, can readily be detected in the gauge glass.

197. Ammonia and oil level gauges.—Generally the ammonia or oil level gauge cocks are fitted with an automatic device which is designed to close the cock if the glass is broken. However, to permit the cock being closed quickly in case of emergency, it is advisable to keep the gauge cocks not more than one-half to one turn open.

198. To replace broken gauge glass.—In the event of the gauge glass being broken, make sure that the cocks are closed tight at once; then unscrew gland nuts from both cocks, removing broken glass, gland

washers, and rubber washers. The new glass should be cut about one-half inch longer than the space between the faces of the upper and lower cocks, so that the glass, when in place, will extend about one-fourth inch into the opening on each cock. Only a good grade of standard Scotch gauge glass should be used. Before putting new glass in place slip gland nuts over glass in proper position; then place the gland washers and finally the rubber washers over the ends of the glass, pushing them firmly into the nut. The glass may now be placed in position with each end extending an equal distance into the recess in the cock, and the gland nut screwed up until tight.

199. For suggestions applicable to all types of machines see articles 217 to 222, and for instructions for operation of brine and ice-making systems see articles 223 to 227.

Section 5.—SULPHUR DIOXIDE MACHINES.

200. Description of refrigerating machine proper.—The Audiffren-Singrum refrigerating machine operates on the same principle as do all compression-type refrigerating machines. Its design, however, differs radically from other machines of this type, as will be seen by reference to the sectional view of the dumb-bell or refrigerating machine proper.

In this machine the refrigerant, sulphur dioxide, and the lubricant are hermetically sealed into the machine at the factory. The charge of both sulphur dioxide and oil is absolutely permanent.

The machine is in appearance a shaft with a drum on one end of it, a second drum in the middle, and a pulley at the opposite end. It is carried in two bearings, one on each side of the drum at the middle of the shaft. If this drum is partially immersed in flowing water and the machine revolved at the proper speed, the drum on the end of the shaft becomes cold and will, of course, cool any material in which it may be immersed. There are no valves to be adjusted in the machine and no gauges to be watched.

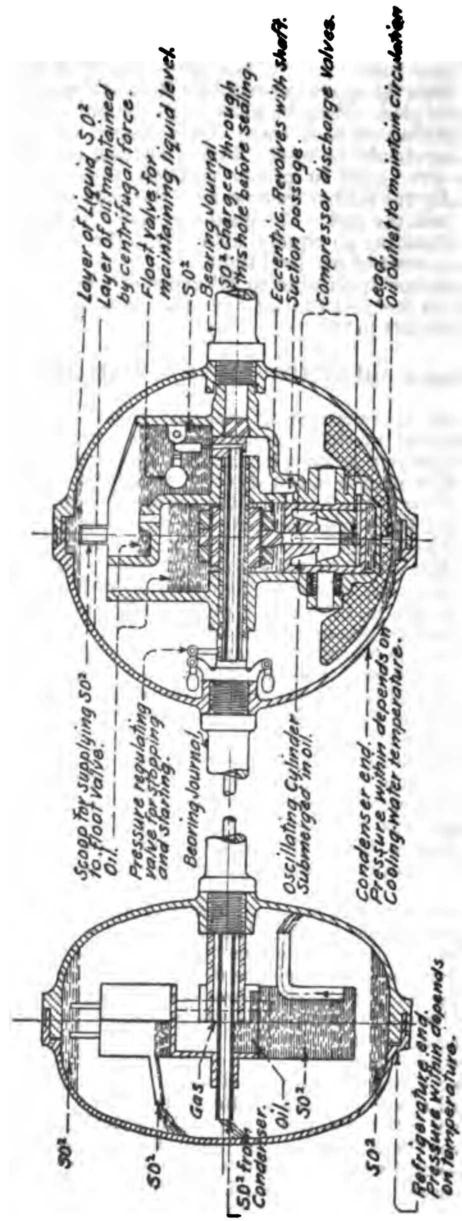
Referring to Figure 25, the compressor hangs on the shaft inside of the spherical drum, this shaft being in effect the crank shaft of the compressor. The compressor is held in position by a counterweight.

The compressor has two double-acting, oscillating cylinders. The suction connection to the cold or evaporating drum is made through the frame of the compressor and through the hollow shaft connecting the two drums.

As the machine revolves, the compressor, being held in position by the counterweight, draws gas from the cooling end of the machine and discharges it through discharge valves in the sides of the cylinder into the condenser drum within which the compressor is itself located.

The gas discharged into the condenser is cooled and liquefied by contact with the walls of this drum, which are in turn cooled by the condensing water flowing about it.

The condensed refrigerant and the oil are held out against the shell of the condenser drum by centrifugal force and are finally caught by means of a small scoop mounted on top of the frame of the compressor and poured down into a separating cup, where the oil is separated and poured back over the compressors to lubricate and cool them while the refrigerant is passed by means of a float valve to the evaporating end of the machine to again evaporate and continue on its cycle.



Layer of Liquid SO^2
Layer of oil maintained by centrifugal force.
Float valve for maintaining liquid level.
SO^2
Bearing Journal
SO^2 Charged through this hole before sealing.
Eccentric. Revolves with Shaft.
Suction passage.
Compressor discharge Valves.
Lead.
Oil outlet to maintain circulation
Scoop for supplying SO^2 to float valve.
Oil.
Pressure regulating valve for stopping and starting.
Bearing Journal.
Oscillating Cylinder Submerged in oil.
Condenser end.
Pressure within depends on Cooling-water temperature.
SO^2
SO^2
SO^2 from Condenser.
Gas
Oil.
SO^2
SO^2
Refrigerating end.
Pressure within depends on temperature.

FIG. 25.

Any lubricant that reaches the cold end of the machine is automatically returned to the condenser end by devices placed in the cold end of the machine.

The pressure in the condenser will obviously be dependent upon the temperature of the condensing water, and consequently the position assumed by the compressor under the control of the counterweight will be dependent upon the temperature of the condensing water. If the supply of condensing water gives out, so that the temperature rises excessively, the counterweight will finally rise to the horizontal position, and any increase in pressure beyond this point will cause the counterweight to revolve with the machine, so that no increase of pressure beyond that for which the counterweight is designed can be caused by the operation of the machine. This acts as a safety device, protecting the machine against damage by failure of condensing water. It will not, however, protect the machine against damage by continous running without condensing water.

If the counterweight begins to revolve with the machine, it will cause it to pound or jerk badly. The machine should be stopped if this happens and more condensing water supplied so as to lower the condenser temperature before attempting to start up again.

201. Direction of rotation.—The proper direction of rotation of the A-S refrigerating machine is with the hands of the clock when facing the pulley end of the machine.

As above stated, the charge of refrigerant and lubricant is permanent in these machines. There is no deterioration either of the oil or of the sulphur dioxide.

202. Speed of machine.—It is important that the speed of the machine be kept approximately correct. The speeds are:

For a No. 2 machine	380 R.P.M.
For a No. 3 machine	280 R.P.M.
For a No. 4 machine	190 R.P.M.
For a No. 6 machine	140 R.P.M.

The first figure of number on end of dumb-bell shaft denotes size of machine. For example, machine 2335 is a No. 2 machine.

203. Standard marine tank design.—In order to avoid spilling of the brine being cooled by the cold end of the machine, or of the condensing water, the brine and condensing water tanks are made of special design. The liquid in each case enters an inner tank in which the machine revolves and overflows to an outer tank from which it flows away, either overside or to a pump.

204. Standard destroyer-type tank arrangement.—In addition to the ordinary marine tank arrangement another design especially developed for refrigerating single compartments is shown in the destroyer-type tank arrangement. In this arrangement the refrigerating machine circulates the brine through cooling coils placed below or to the side of the machine. The brine is thrown into a scoop by the action of the machine and flows by gravity through the coils and back into the tank.

Spilling of brine over the tank edge is avoided by a labyrinth arrangement around the opening, through which the shaft passes out of the tank, the joint between the cover and the tank being made water-tight except at this point. No inner tank is used in this design.

205. Care of refrigerator.—The best results will be obtained by dividing the time the machine must run each day into two parts, running it for a while early in the day and again late in the afternoon, increasing the length of these running periods as the weather may require.

The machine should be run each day only so long as is necessary. This time will depend upon the condition of the refrigerator, on the amount and temperature of the material in it, and especially upon the weather.

Keep the refrigerator doors shut tight.

Keep the refrigerator, the machine, and its surroundings clean.

Do not allow anyone to place goods in the refrigerator so close together that the air cannot circulate up through the storage compartment. Do not cover the shelves with paper. The refrigerator is cooled by the circulation of air downward along the cooling surface and upward through the food compartment. The goods must be stored to interfere as little as possible with the free circulation of the air.

206. Making ice.—Fill the ice molds with water to such a level that motion of the ship will not cause it to overflow. Remove the ice molds from the ice-making cabinet while filling them. This is to avoid spilling water into the brine, which weakens the brine and requires frequent addition of salt or calcium.

In harvesting the ice it will be found frozen tight in the mold when it is taken from the brine. If allowed to stand in the air for a few minutes it will melt loose. Loosening may be hastened by dipping the mold into warm, not hot, water. Do not hammer the ice mold or rap it on the deck.

207. Brine.—Always keep the brine below 32° F. If it rises above this temperature, the ice will loosen in the mold, and in refreezing the can will be forced out of shape and probably leak.

Keep the brine strong. The salometer should float in the brine between 75° (1.125 specific gravity) and 90° Baumé (1.184 specific gravity). If it floats lower than 75°, add salt, being careful in doing this to avoid getting dirt into the system. Loose salt is apt to clog the pipes. Make the brine outside of the machine and strain it before placing it in the tank.

A good method of keeping the brine up to proper strength is to hang a bag of salt directly in the brine.

Take care to maintain the brine level at the proper point. Where the brine is circulated by a pump, do not allow it to fall low enough in the overflow compartment to uncover the suction strainer. In the destroyer type of tank test the level of the brine by the pet cock on the brine tank. Make this test when the machine is not running. If brine does not flow from the pet cock add brine until it does flow.

When the system is first filled with brine, listing of the vessel may cause air pockets in brine coils, so that after machine is run a day or so and air has been removed from the coils by circulation of the brine there will be a lowering of the brine level in the tank, which should then be brought up to the proper height.

Either rock salt or calcium chloride may be used for making brine.

If calcium chloride is used for making brine, be sure that the solution has cooled down to ordinary temperatures before the machine is started.

If either calcium or salt brine is weak, the corrosion will be considerable, but if they are kept up to the strength above indicated neither one causes serious corrosion.

208. Condensing water.—Be sure that there is water flowing through the condensing tank when the machine is running—enough so that there will be not more than 4° F. difference in temperature between supply and overflow.

209. Capacity.—The capacity of the machine varies as the temperature of the condensing water at the rate of about one per cent for each degree change in temperature. For instance, with condensing water at 60° F., the cooling capacity of machine would be 20 per cent greater than with condensing water at 80 ° F.

Do not allow the surface of the condenser drum to accumulate incrustations of any kind. These interfere with the flow of heat and seriously reduce the capacity of the machine.

If the condensing water comes to the refrigerating machine through a very warm engine room, it is a good plan to turn on the water for a little time before the machine is started.

210. Lubrication.—The main bearings on the dumb-bell are provided with wick oilers and oil chambers at the bottom and should be kept well oiled. Wicks should be removed once a week and examined to see that they are feeding properly.

211. Belt.—Do not use rosin on belt. The best dressing for belt is castor oil. This should be applied extremely slowly. Do not under any circumstances attempt to pour a small quantity on to the belt. Put it on with a small stick, a very little at a time, and allow it to work over the belt thoroughly. Castor oil will not harm the belt in any way; in fact it will improve its life and at the same time will make it cling to the pulley.

212. Continuous operation.—The refrigerating machine is designed to run continuously, if necessary, and will not be damaged if it should run several months without stopping. In this case, however, an excessive amount of frost may gather on the coils in the refrigerator. This will insulate the coils so that the brine will tend to become colder and colder without properly cooling the refrigerator. It will then be necessary to shut the machine down long enough to allow the frost to thaw off the pipes. It is better, therefore, to allow the frost to melt off the coils often enough to prevent heavy accumulation.

Continuous operation of the machine under normal conditions is not necessary. As above stated, best results are obtained by dividing the time the machine must be run each day into two or more parts, running it for a while early in the day and again late in the afternoon, increasing the length of these periods as the weather may require.

213. Precautions to be taken in starting machines when new or after long periods of idleness.—When a dumb-bell has been out of service for a number of weeks or months, the oil drains off of the bearings of the internal mechanism. Therefore, in restarting the machine it is necessary to insure getting lubrication to all bearing surfaces within the machine before they have a chance to heat and stick.

Before putting power on the dumb-bell it should be turned over by hand for several minutes in the case of the smaller machines. In the case of the larger machines turning by hand would necessarily be so slow a process as to be ineffective in getting oil to the bearings. Large machines should, therefore, be turned over by power for a few seconds, doing this repeatedly. These running periods should be from 10 to 20 seconds and should be repeated perhaps a dozen times. This will start the oil circu-

lating and give the bearings some lubrication before the machine is run at full speed and full load.

Sufficient condensing water should be flowing to keep the condenser as cool as possible during this period.

If it is practicable, it is a good thing to operate the machine for a time without allowing the liquid in the evaporator cabinet to touch the dumb-bell. This can, of course, be done in starting new machines without any difficulty. During the time, however, that the machine is run in this way, it is important to frequently brush off the frost that forms on the cold end of the machine. Otherwise, a heavy insulating coating is formed over this surface, with the result that the interior of the machine becomes excessively cold. This condition of excessively low temperature in the cold end of the machine must be avoided, because the lubricating oil becomes very sluggish at from 10 to 15 degrees above 0° F., and congeals in a temperature of from 4 to 9° below 0°F. Consequently at low temperature the oil returns very slowly to the compressor, and if the machine is allowed to operate for a considerable length of time under these conditions the oil level in the compressor end of the machine will be seriously lowered.

It is perhaps a safer practice to stop the machine from time to time and leave it idle long enough for the frost to melt off. This gives visible assurance that the temperature in the cold end is not excessively low, and this intermittent operation is further beneficial in insuring lubricating oil being thoroughly distributed inside of the machine before a heavy or continuous load comes on to these parts.

Before starting the machine after having stopped it, time must be given for the gas pressure to equalize before it is started, otherwise the compressed gas in the condenser end will make the machine very stiff in starting and may throw the belt or result in a turnover of the counterweight. Allow at least a minute or so to elapse before starting after a shut down.

After having run the machine for a time with the cold end exposed to the air, the liquid in the evaporator cabinet may be raised to bring it into contact with the cold end of the dumb-bell. When you do this, the liquid should be allowed to just touch the rim of the bell.

When the liquid has fallen to say 55°F., the level may be raised very slowly, being sure that at no time it is allowed to rise above 55°F. as the level is raised.

214. Laying up the machine (see N. Eng. 388 (44)).—In laying up the machine do not drain the brine out of the system unless you are in a position to remove it thoroughly by flushing it out with water and then later remove all of the water. If the system is left full of brine, take care that the brine shall be of full strength—that is, 80° or 90° on the salometer.

The belt driving the machine should be taken off and stored in a dry place, and the shaft of the machine and any other steel parts exposed to the atmosphere should be given a coat of No-Ox-Id, Whiz, or other similar compound.

215. Failure to refrigerate.—If the refrigerating machine fails to cool the refrigerator, first turn the machine over by hand to see if it turns freely. Second, examine the speed to see that the machine is operating at the proper number of revolutions per minute. Third, examine

the brine to be certain that it is of proper density so that it can not freeze on the drum of the machine and so interfere with proper refrigeration. Fourth, in the destroyer type of installation, be sure that the brine level is correct and that the brine coils are not clogged. Fifth, see if the suction to the brine pump is always full of brine. Sixth, remove enough brine so that the cold end of the machine is free to revolve in the air. Operate the machine for 15 minutes or so and see if the cold end will frost up. Under no circumstances open up the dumb-bell, for to do so will permit the contained gas under pressure to escape and thereby destroy the refrigerating properties of the machine.

216. For suggestions applicable to all types of machines see articles 217 to 222, and for instructions for operation of brine and ice-making systems see articles 223 to 227.

Section 6.—OPERATING SUGGESTIONS APPLICABLE TO ALL TYPES OF MACHINES.

217. **Cool circulating water in the Tropics.**—In the Tropics it frequently happens that the surface water is warmer than the water below and some ships have rigged a suction hose over the side so that the cooler water may be used for circulating water, thereby increasing the capacity of the ice machine.

218. **Washing out the cold-storage rooms.**—The cold-storage rooms should be washed out and thoroughly cleaned at least once every three months, as they will soon have a very disagreeable odor due to the gradual accumulation of blood and small pieces of meat.

219. **Blower in cold-storage room.**—The time required to reduce the temperature of a cold-storage room can be reduced and the efficiency of the plant increased by installing a blower in the cold-storage room so that it discharges against the cooling coils and sets up a circulation of air throughout the room. On the *Paducah* an installation of this kind is made as follows: Motor is installed on bulkhead outside of storage room. Speed reduction is obtained by inserting a 32-candlepower lamp in series on supply line to motor. Fan and casing were disconnected from shaft of motor and installed in the storage room. Fan is installed on a long shaft passing through a galvanized-iron pipe fitted in hole drilled through storage-room bulkhead. Galvanized-iron pipe is made air and water tight by special fittings. Fan shaft is supported by ball bearings on storage-room end, and a stuffing box with flax packing is fitted at motor end, both the ball bearings and stuffing box being fitted in the galvanized pipe. The motor shaft and fan shaft are connected by a flexible coupling. The motor is shut down before entering storage room, and also whenever cold air is shut off for any purpose.

220. **Moisture absorber.**—Water in the piping of a plant of any type will prove troublesome by freezing and causing a stoppage in the low-pressure side of the system. The water enters the system when charging in a CO_2 or ammonia plant or through the primer pump in a dense-air plant. An effective means of preventing moisture entering the system is the use of a moisture absorber or gas drier installed in the charging pipe.

A moisture absorber which was manufactured aboard ship and installed in the charging pipe of a CO_2 machine is shown in figure 26. No further trouble with moisture freezing in the system was experienced

after installation of this absorber. Its use with a dense-air machine, as well as other types where none is now installed, would practically eliminate the troubles due to moisture in the system.

221. Lubricating oil.—It is important that the proper oil be used for lubricating the cylinders and piston rods of ice machines. Oil having a low cold test is necessary as otherwise it would congeal when in contact with the cold gas or air returned to the compressor. The oil especially provided for this purpose should be used, and to prevent the accidental use of oil for bearings or the driving unit in the ice-machine cylinders the cans containing the different oils should be plainly marked.

222. Storage of drums containing refrigerant.—The refrigerant used in the various types of refrigerating plants installed aboard ship, with the exception of the dense air and Audiffren-Singrum types, is supplied in drums or containers and is placed in these drums under pressure.

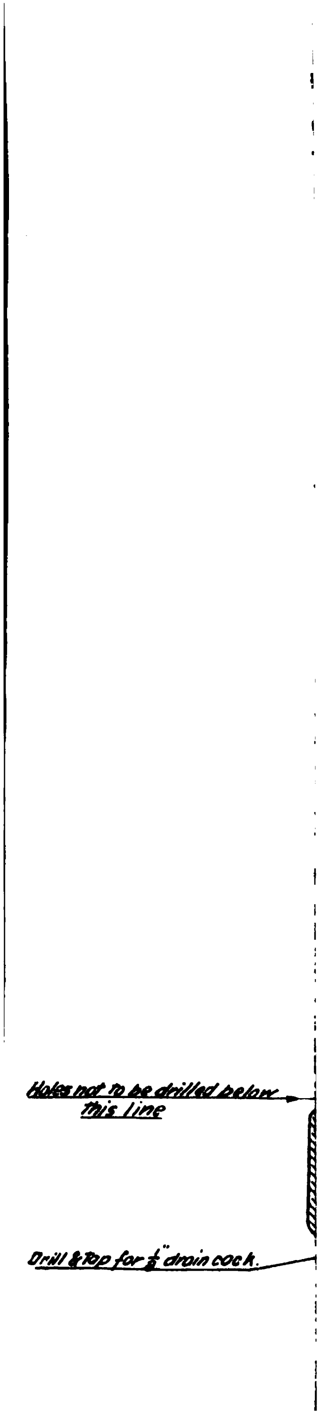
The drums should be stored in a cool place, because when they are exposed to a temperature higher than that at which they were filled the pressure of the gas in the drums is correspondingly increased, which will become dangerous if the temperature is sufficiently high.

Section 7.—INSTRUCTIONS FOR OPERATION OF BRINE AND ICE MAKING SYSTEMS.

223. Density of brine solution.—Where brine is used as the cooling medium, particular attention should be paid to its density. A weak solution will be liable to freeze and also to cause corrosion, while a solution that is stronger than necessary will reduce the efficiency of the plant, as the specific heat, and consequently its heat-conducting ability, is lessened as the solution is made stronger. Furthermore the stronger the solution the more likely it is to form a coating on the inside of the cooling coils. The accompanying tables give the freezing points for brine solutions of various densities together with the approximate quantities by weight of calcium chloride or sodium chloride (common salt) required per gallon of water to obtain brine of the required density.

CALCIUM CHLORIDE ($CaCl_2$).

Specific gravity at 60° F.	Degrees salometer at 60° F.	Pounds $CaCl_2$ per gallon of solution (approx.).	Freezing point ° F.
1.024	12	½	29.5
1.049	26	1	26.6
1.076	40	1½	22.8
1.103	52	2	18.1
1.131	68	2½	12.2
1.160	80	3	4.6
1.188	92	3½	− 4.9
1.218	104	4	−17.1
1.250	116	4½	−32.6



Holes not to be drilled below this line
Drill & Tap for 1/8" drain cock.

SODIUM CHLORIDE ($NaCl$) (COMMON SALT).

Specific gravity at 60° F.	Degrees salometer at 60° F.	Pounds NaCl per gallon of solution (approx.).	Freezing point, ° F.
1.044	22.7	½	23.9
1.089	45.2	1	16.0
1.119	60.6	1½	11.0
1.159	79.1	2	5.0
1.192	94.7	2½	0.0

The density of the brine should be such that the freezing point is from 10 to 15°F. below the temperature to which the brine is to be cooled in the brine cooler. Likewise, the density of the still brine in the ice-making tanks should be sufficient to lower its freezing point until it is from 0° to 5° F. The density of both the circulating and still brine should be ascertained at least once a month and a stronger solution added if it has become weak.

224. Calcium chloride preferable to sodium chloride.—When making the brine solution, the use of calcium chloride is preferable to sodium chloride, as a lower freezing point can be obtained with the former and the corrosive action of calcium chloride brine is less than that of brine made with sodium chloride.

225.—Mixing the brine.—The calcium chloride should always be completely dissolved before being added to the system. Lumps of calcium chloride should never be thrown into the cooler, if of the open type, or into the ice-making tank.

Some plants in which the brine cooler is under pressure are equipped with a brine-mixing tank, which is connected to the brine-pump suction with a cut-out valve in the line between the mixing tank and the pump-suction line. The tank is usually cylindrical, about 24 inches in diameter by about 3 feet high, with a removable cover and a ⅛-inch-mesh wire screen fitted about 6 inches from the bottom. The outlet is located below the wire screen. After mixing the brine in this tank, it can be pumped into the system by opening the cut-out valve while the brine pump is running. If no mixing tank is installed, the brine must be admitted to the system through a hose or pipe connected to the brine-pump suction, or it can be poured into the brine tank if it is of the open type.

226. Regulating the flow of brine.—The temperatures in the various cold-storage rooms should be regulated by controlling the amount of brine flowing through the coils of each room. The temperature of the brine leaving the cooler should be about 15° F. below the temperature to be maintained in the coldest rooms. The difference between the temperature of the brine leaving the cooler and that entering the cooler after having passed through the rooms should be from 3° to 3½° F., and the flow of brine should be regulated to obtain this difference. Care should be taken to vent the air from the brine system and prevent an unnecessary pressure in the brine lines. The brine should be kept as clean as possible to prevent clogging up of the lines.

227. Ice making.—When pouring brine into the ice-making tank, enough brine only should be added to cover the coils, as too high a level will cause it to splash into the fresh water in the cans. Ice cans should be filled with fresh water to a level about 2 inches from the top. In filling the cans, care should be taken that the water is not spilled into the brine in the tank. It is good practice to fit the end of the ice-can-filling hose with a vertical check valve, so that the pressing of the valve stem on the bottom of the can will open the valve and fill the can from the bottom, driving out the air and reducing the amount which is usually mixed with the water in filling the cans. In order to secure good clear ice, the freezing should be done slowly, as much time as possible being allowed for this purpose. Whenever an ice can is removed and the ice has been taken out the can should be immediately replaced and clamped down. The ice cans should be frequently examined for leaks, as a small leak will render the ice very disagreeable to the taste.

O